April 1989 DCIEM Report #89-RR-14

SEASICKNESS IN OCCUPANTS OF TOTALLY-ENCLOSED MOTOR-PROPELLED SURVIVAL CRAFT (TEMPSC)

by

JACK P. LANDOLT, Ph.D., P.Eng.

CHARLENE MONACO, B. Eng.

Defence & Civil Institute of Environmental Medicine
1133 Sheppard Avenue West
P.O. Box 2000
Downsview, Ontario
M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	iii
CHAPTER 1. INTRODUCTION	1
1.1. General	1
1.2. Project Strategy	1
1.3. Report Format	2
CHAPTER 2. SEASICKNESS	3
2.1. The Neurosensory Mismatch Concept of Motion Sickness	3
2.2. The Sensory Organs for Spatial Orientation and Motion Sickness	4
2.2.1. The Vestibular System	6
2.2.2. The Visual System	6
2.3. Sensory Organ Mismatches for Provoking Motion Sickness	9
2.3.1. The Vestibular Coriolis Effect -- A Semicircular Canal-Otolith Mismatch	9
2.3.2. The Pseudo-Coriolis Effect	9
2.4. Neurosensory Mismatches Associated with Typical Forms of Motion Sickness	10
2.4.1. Car Sickness	10
2.4.2. Seasickness	11
2.4.3. Air Sickness	12
2.4.4. Simulator Sickness	12
2.4.5. Space Sickness	13
2.5. Neurosensory Mismatch Conditions Specific to TEMPSC	13
CHAPTER 3. RELATIONSHIP BETWEEN SHIP MOTION AND SEASICKNESS	18
3.1. Frequency of Ship Motion	18
3.2. Ship Motion Acceleration Magnitudes	18
3.3. Relating Heave Motion to Seasickness	20
CHAPTER 4. REVIEW OF SEASICKNESS IN MARINE DISASTERS	25
4.1. Literature Review Pertaining to Survival-at-Sea	25
4.2. Canadian Coast Guard Reports	26
4.3. A Review of Some Marine Disasters in the United Kingdom.	26
4.4. Incidents Involving TEMPSC Occupants	27
4.4.1. Alexander L. Kielland Disaster	27
4.4.2. Ocean Ranger Disaster	29
4.4.3. Vinland (Uniacke G-72) Incident	30
4.4.4. Ocean Odyssey Incident	32
4.4.5. Rowan Gorilla I Incident	33
4.5. Commentary on Seasickness Endangering Life in TEMPSC	34

Page

CHAPTER 5. CONTROLLING SEASICKNESS IN TEMPSC OCCUPANTS..... 38

5.1. Sea Conditions in Eastern Canadian Coastal Waters..... 38
5.2. Singapore Navy Study of Seasickness Prevention..... 38
5.3. Habitability of TEMPSC in Moderate-to-Rough Seas..... 42

5.4. Drug Therapy..... 43
5.4.1 Methods of Drug Administration..... 44

5.5. The Management of Vomiting in Seasickness in TEMPSC Occupants..... 50

CHAPTER 6. CONCLUSIONS..... 54

CHAPTER 7. RECOMMENDATIONS..... 57

CHAPTER 8. ACKNOWLEDGEMENTS..... 59

CHAPTER 9. REFERENCES..... 61

APPENDIX I: Rowan Gorilla I Motion Sickness Questionnaire: Summary of Results

APPENDIX II: Auto-Injectors for Self-Administration of Antidotes against Chemical or Nerve Agents

APPENDIX II: Index of Fact-Finding Visits

EXECUTIVE SUMMARY

1. The Defence and Civil Institute of Environmental Medicine (DCIEM) was contracted by Canada Oil and Gas Lands Administration (COGLA) to assess the degree to which seasickness endangers the lives of TEMPSC occupants, and to give advice on how the problem might be alleviated.

2. Thousands of peacetime marine incidents were reviewed. The one reported death in the Vinland abandonment appears to be the only one that could be associated, even remotely, with seasickness. The death in question was most likely caused by a combination of severe stress factors: anxiety, fear of evacuating the rig, claustrophobia, etc. Seasickness, if it played a part at all, was a minor contributing factor. With no access to the victims medical history, it is impossible to determine whether or not there were any predisposing familial or personal risk factors.

3. The small size of the TEMPSC almost guarantees that all or most of the rig evacuees will become seasick. In the oil rig abandonments associated with the Alexander L. Kielland, Vinland, Ocean Odyssey and Rowan Gorilla I incidents, seasickness occurred in 75% or more of TEMPSC occupants. (The Ocean Ranger disaster was also studied, but it was not possible to establish whether or not its victims had been seasick.)

4. The real danger of seasickness in TEMPSC occupants is the fact that severe vomiting causes dehydration and loss of body electrolytes that, if left unchecked, contribute to a serious loss in morale and the will to survive, along with a total loss of interest in everything, including participation in survival or rescue attempts.

5. Notwithstanding the problems with seasickness, the Rowan Gorilla I incident has clearly shown that evacuees in an intact TEMPSC should not be rescued until the weather and sea conditions improve. If there is severe damage to the TEMPSC, as in the case of the Ocean Ranger disaster, then rescue attempts should be made taking into consideration weather and sea conditions.

6. Nothing can be done with the overall design of current TEMPSCs to reduce seasickness; therefore, efforts should be made to improve the habitability of the TEMPSC in order to reduce seasickness-provoking conditions and improve comfort. In particular, it is necessary to provide climatic control to regulate the temperature, remove odours and provide sufficient fresh air to prohibit the buildup of carbon dioxide and carbon monoxide.

7. Antimotion sickness drugs are the most effective way of controlling vomiting from seasickness. Since many TEMPSC occupants will become seasick and vomit within 15 minutes of rig abandonment, it is necessary to introduce the drug rapidly into the blood. Long-term protection is also needed, as the TEMPSC occupants may be at sea for 36 or more hours in Eastern Canadian offshore waters before rescue can occur. Indications are that both quick-acting and long-term protection can be accomplished by administering an intramuscular injection of scopolamine -- the drug of choice -- as soon as the call for rig evacuation is given, then following up with the application of a transdermal scopolamine patch behind the ear.

8. Many recommendations are given in this report. They can be considered in terms of two phases: those that should be implemented for immediate protection and comfort; and long-term solutions, which would require novel approaches to TEMPSC design and antimotion sickness drug delivery.

CHAPTER 1.

INTRODUCTION

Seasickness is universally acknowledged to be a most unpleasant experience, and, in its extreme form, leaves the victim unwilling even to assist in his/her own rescue. In 1984, following a rescue off Sable Island, Nova Scotia from a totally-enclosed motor-propelled survival craft (TEMPSC) carrying personnel from the abandoned oil rig, Vinland, one 31-year-old man subsequently died. All aboard the TEMPSC were extremely seasick, and it has been suggested that this was a contributing factor in the man's death. This incident precipitated debate concerning the necessity of recovering evacuees from a TEMPSC as soon as possible. On the one hand, it was argued, resources should be committed to developing techniques to recover TEMPSC occupants as an alternative to prolonged lifeboat confinement. On the other hand, it was argued that any transfer technique at sea is risky, and having safely evacuated a drilling unit, evacuees should be left in the TEMPSC until sea conditions are sufficiently moderate to ensure safe recovery of personnel by conventional means. Resolution of the debate (aside from other factors) appeared to be the comparison of the risk involved in undertaking a transfer at sea under adverse conditions against the risk of prolonged exposure to rough seas while in the TEMPSC.

1.1. General

This report describes the findings of a study conducted by the Defence and Civil Institute of Environmental Medicine (DCIEM) for Canada Oil and Gas Lands Administration (COGLA). The purpose of the study was to assess the degree to which prolonged exposure to seasickness endangers the lives of TEMPSC occupants and give advice as to how the problem can be ameliorated.

1.2. Project Strategy

The objectives of the study, as dictated by COGLA's Statement of Work, and more recent events, were as follows:

a. to review the accident reports and other relevant material on the oil rigs Ocean Ranger, Alexander L. Kielland, Vinland (Uniake G-72 incident), Ocean Odyssey and Rowan Gorilla I, along with reports supplied and/or identified by COGLA and the Canadian Coast Guard/Search and Rescue Branch;

b. to conduct a literature search of marine disasters and identify well-documented cases relevant to the subject matter for inclusion in the final report of the study; and

c. to review the appropriate scientific literature on the causes and effects of motion sickness, with particular emphasis placed on how they relate to the problem of seasickness in TEMPSC occupants.

.../2

1.3. Report Format

The report deals, first, with a review of seasickness, its signs and symptoms, the phenomenon of protective adaptation, the neurosensory mismatch concept of motion sickness, the roles of the vestibular and visual systems in spatial orientation and motion sickness, specific examples of motion sickness (car sickness, air sickness, seasickness, simulator sickness and Space sickness), and mismatch conditions within current TEMPSCs which may contribute to the seasickness problem.

Chapter 3. discusses the way in which the characteristics of frequency, magnitude and duration of ship motion affect the incidence of seasickness.

In Chapter 4. the importance of seasickness as a cause of death in marine disasters is reviewed. The chapter begins with the findings of a literature review which indicates that seasickness can lead to dehydration, loss of morale and a predisposition to hypothermia (loss of body heat). Reports of the Canadian Coast Guard and the Royal Navy concerning marine disasters provide no evidence that seasickness was a causative factor in the loss of lives at sea. The chapter closes by concluding that there is no concrete evidence to suggest that seasickness contributed to loss of life or endangered the lives of TEMPSC occupants in the oil rig disasters Alexander L. Kielland, Ocean Ranger, Vinland, Ocean Odyssey and Rowan Gorilla I.

Chapter 5. deals with the very important subject of how to control seasickness in TEMPSC occupants. It begins with a discussion on sea conditions in the Eastern Canadian coastal waters; and then relates this to the most up-to-date published literature from the experience of the Singapore Navy in preventing seasickness. Finally, it elaborates on habitability in a TEMPSC in moderate-to-rough sea conditions, and ends by describing antimotion sickness drug therapy, with specific discussion concerning the drug of choice and the methods of delivery for controlling seasickness in TEMPSC occupants.

Chapters 6. and 7. complete the study with conclusions and recommendations for further action.

.../3

CHAPTER 2.

SEASICKNESS

According to an ancient proverb, "The world can be divided into three classes: the living, the dead and the seasick." (Anarcharsis, AD 500 -- cited in (29)). Many a mariner heartily agrees with this time-honoured truth. The incidence of sea sickness in inexperienced passengers can range from 25-30% in moderate sea states to 90% or more in rough seas (5,10,36). Severe seasickness can, if unalleviated, actually lead the sufferer to develop a death wish.

Seasickness is the most common form of motion sickness. It is characterized primarily by the following signs and symptoms: pallor, cold sweating, nausea and vomiting. Associated with these signs and symptoms is a general feeling of malaise. Less reliable and consistent signs and symptoms have been reported in the literature, including drowsiness, yawning, headache, stomach awareness, social indifference, mental confusion and others (34,38). The onset and severity of motion sickness is dependent on several factors: the intensity, frequency, direction and duration of the motion stimulus; the individual's susceptibility; the nature of the task performed and the head movements made by the individual; and the influence of other environmental factors such as odours (4,5).

2.1. The Neurosensory Mismatch Concept of Motion Sickness

When Man first evolved, his various sensory organs gave him information about how his body was positioned and actively moving about in his confined earthbound environment. That information was accumulated and integrated by the brain to form a memory store with which new sensory information could be evaluated, expanded and compared. When required, the brain sends out corrective postural reflex signals that keep the body properly oriented in space as Man actively moves about. As long as the different sensory organs provide congruent information, in tune with what is expected by the brain, then the conditions for the proper perception of motion and orientation are well-defined and unequivocal. When the information received is incongruent with the perceptual expectations dictated by the memory stores; that is, when the attitudinal information and motion perceived by the sensory organs are in conflict with the reality of the situation, then the conditions for spatial disorientation and motion sickness are at hand. This is precisely what happened to Man when he first ventured outside his fixed earthbound environment; in particular, when he first took to ships on the high seas and became, himself, a passive object in a moving environment.

The term "sensory conflict" has been associated with the condition in which inconsistent sensory information arrives at the brain integrating centres that are involved in the maintenance of proper spatial orientation (11). Reason and Brand (46) extended this concept to a "neurosensory mismatch" construct by advancing the premise that

.../4

motion sickness occurs when incongruent sensory information is incompatible with our expectations for it, based on memory stores of previous experiences. Figure 1 is a diagrammatic representation of the components and processes that define the neurosensory mismatch construct. The basic reason that neurosensory mismatches of this kind cause vomiting is that the brain responds to them as if poisoning has occurred; and, indeed, some poisons do create mismatches in the brain (11,37,57).

The neurosensory mismatch construct is intuitively appealing because it also takes into account the phenomenon of adaptation (or protective adaptation, in the terminology of Reason and Brand). In motion sickness parlance, adaptation has taken place when the incongruent sensory information has become compatible with our new experiences of it as dictated by the updated memory stores. That is to say, adaptation occurs when one finally becomes accustomed to the continuos exposure to the motion stimulus. Adaptation to motion takes place over a period of approximately 3-4 days, at which time the symptoms of motion sickness disappear (for example, see How et al., (23) for time taken to adapt to sea motion).

2.2. The Sensory Organs for Spatial Orientation and Motion Sickness

Man's perception of orientation on Earth is governed by the integrative action of brain centres on sensory information received from the balance organs of the inner ear, that is, the labyrinthine vestibular organs (semicircular canals and otoliths), the visual sensors of the eyes, and from non-vestibular proprioceptors and tactile receptors (the sensors of movement and position in body tissues, tendons, muscles and joints -- referred to as "other mechanoreceptors" in Figure 1). To a much lesser extent, the senses of hearing and smell may also play a role in spatial orientation. Smell certainly plays a very important role in inducing motion sickness.

There is compelling evidence suggesting that the vestibular nucleus (which is located in the brain stem) or the cerebellum is the primary centre at which the integration of spatial sensory information from the vestibular and visual organs takes place (4). Waespe and Henn (60) recorded neural activity in the vestibular nucleus in the unanesthetized monkey and have shown that it can be modulated by vestibular stimuli alone, by purely visual means, or by a combination of both.

Labyrinthine-defective individuals, such as deaf mutes, and animals which have had their vestibular organs removed or their nerves sectioned for some time do not become motion sick. Such observations provide irrefutable evidence that the vestibular organs play an essential role in the genesis of motion sickness. Following destruction of the labyrinths, patients and animals continue to become motion sick while the vestibular nuclei gradually cease to function. Once they no longer function, it is no longer possible to become motion sick, which implicates the vestibular nucleus as an essential component in causing

.../5

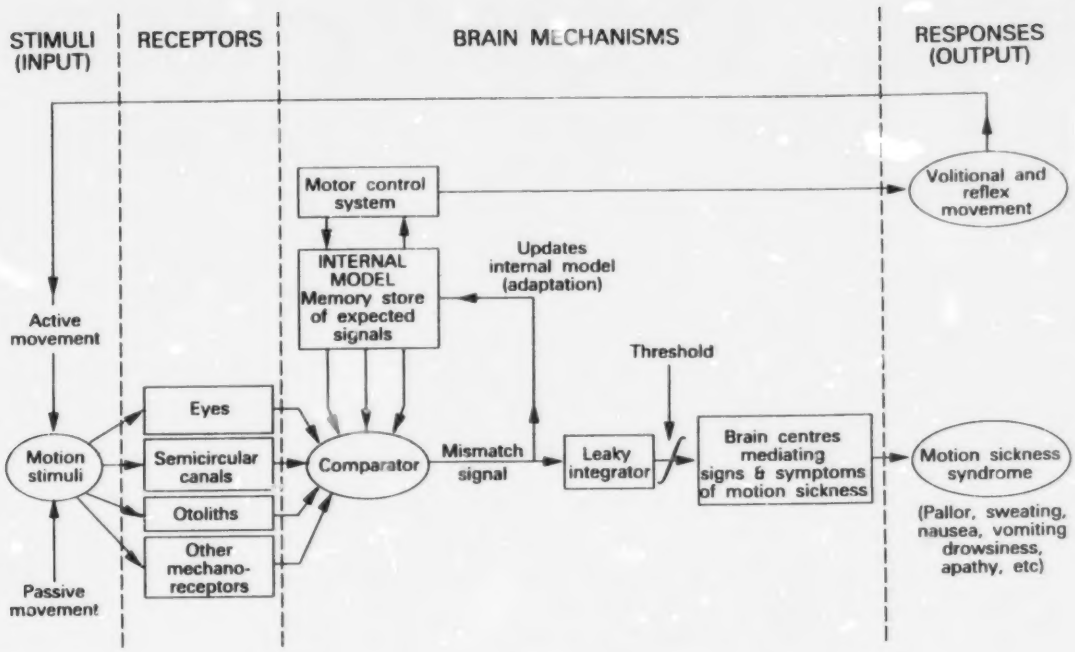

FIGURE 1 Components and processes of "neurosensory mismatch" construct (modified from Benson (4)).

.../6

motion sickness. Visually-induced motion sickness, which occurs when a stationary subject views a moving visual field, also appears to require a functioning vestibular nucleus. Proprioceptive and tactile receptors may also impinge upon the vestibular nucleus. In any case, a viable vestibular apparatus is required in order to have a functional vestibular nucleus. People missing their vestibular apparatus for some time do not get seasick. However, blind people do have functioning vestibular nuclei and, accordingly, they can get seasick.

2.2.1. The Vestibular System

Anatomically, the vestibular labyrinth is comprised of the semicircular canals and the otoliths (Figure 2). The planes of the three semicircular canals of one ear are approximately mutually perpendicular to one another, and are paired with the parallel canals of the other ear (Figure 3b). Their function is to sense angular accelerations of the head for all directions of motion. The planes of the two otoliths are perpendicular to each other and are also paired on each side of the head (Figure 3a). They sense linear accelerations of the head and the direction of gravity, relative to the head. Together, the vestibular system and the non-vestibular proprioceptors and tactile receptors continuously determine the position and movement of the body in space at all times. The vestibular system also coordinates eye and body movements by enabling the eyes to remain stabilized on a fixed point in space.

2.2.2. The Visual System

The semicircular canals and otoliths respond to accelerations and decelerations of the head; they do not respond to constant rotary or linear velocities. During constant velocity body motion, the sensation of body movement is governed almost exclusively by the sense of vision.

When a person actively moves about relative to a stationary scene (for example, in jogging), the image of the scene moves across the retina, exciting visual motion detectors. The brain correctly perceives the signals from these detectors as coming from a stationary scene. The vestibular and non-vestibular spatial senses ascribe the motion signals to self-motion. However, when one is moved about passively (for example, as a passenger in a vehicle), rather than moving about volitionally, the perception of whether or not the stationary scene is indeed stationary is impaired. Illusions of scene motion under such conditions are known as oculogyral illusions (24).

When stationary subjects look at a wide-angle moving visual scene, after a few seconds they typically perceive it to be stationary, and perceive themselves to be moving in the opposite direction. If the scene rotates around the subject, then the visually-induced sensation of self-rotation is called circular vection. When the motion of the scene is linear, the person is said to experience linear vection or visually-induced self-translation. Vection is commonly induced in an occupant in a stationary train by a moving neighbouring train, by watching wide-screen cinemas or by some types of flight simulators.

.../7

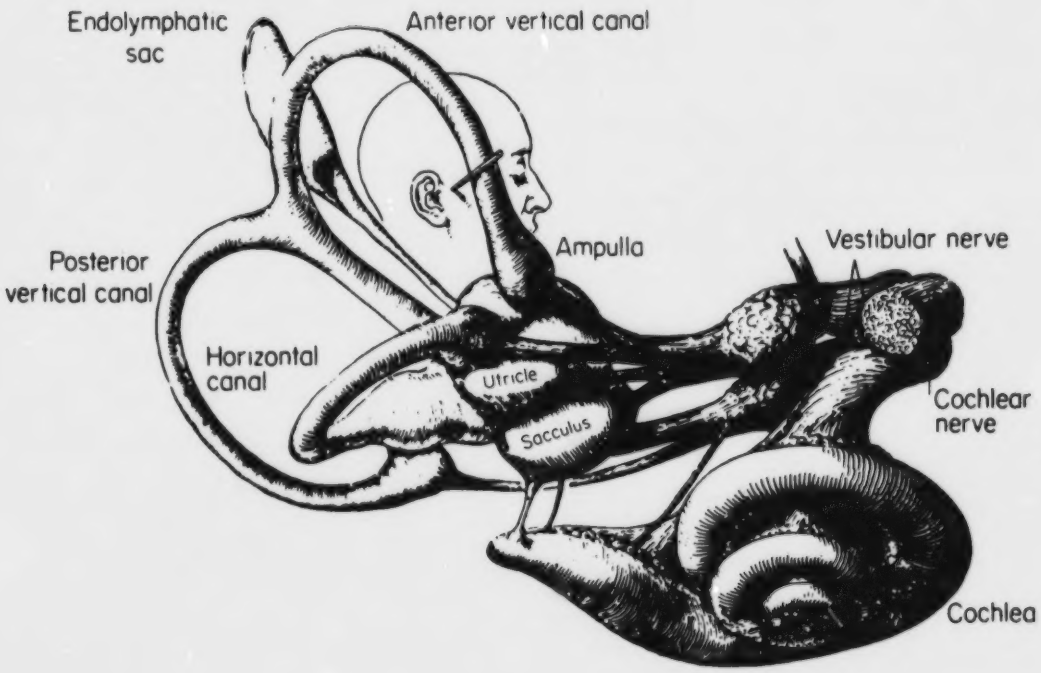

FIGURE 2 Diagram of inner ear showing the balance organs for sensing angular accelerations (the three semicircular canals) and linear accelerations (the utricle and the saccule), and the organ of hearing (the cochlea) together with the nerves connecting them to the brain (from Hardy (22)).

.../8

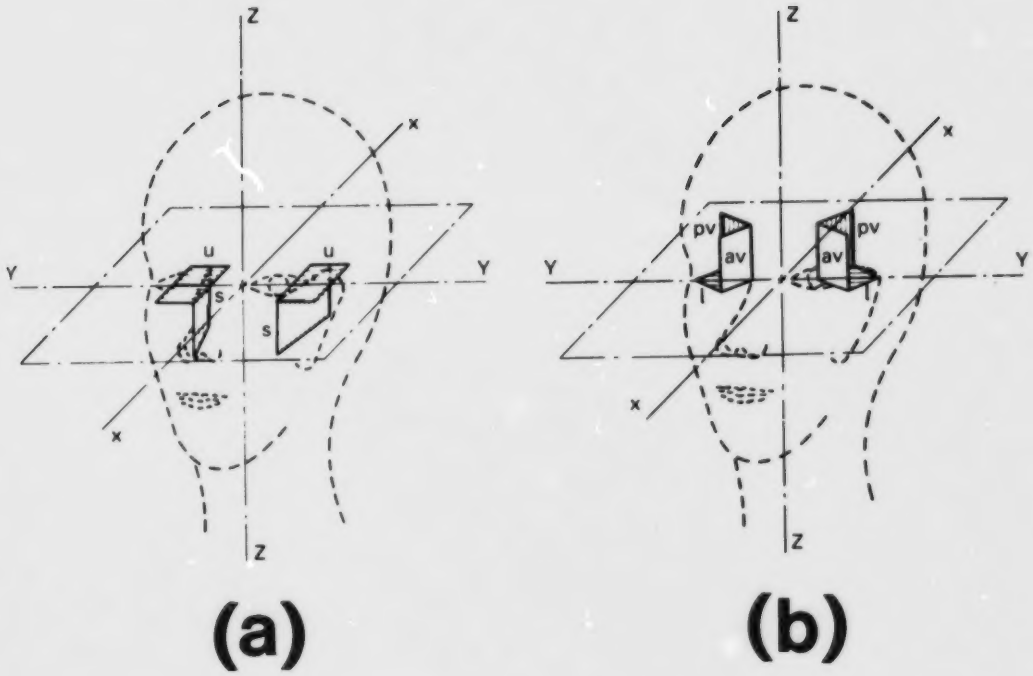

FIGURE 3 Illustration of the approximate planes of: (a) the otolithic organs (utricle (u) and saccule (s)), and (b) the semicircular canals (pv, av, l represent posterior, anterior and lateral semicircular canals, respectively). X, Y and Z are principal axes of the head (from Barnes (3)).

.../9

Body sensations produced as a result of vection are almost identical to those occurring with active body movements. This suggests that visually-induced motion has the same effect as does stimulation of the vestibular organs. Thus, it is not surprising that convergence of visual and vestibular inputs occurs in a common brain centre, probably the vestibular nucleus, as indicated earlier in this section.

2.3. Sensory Organ Mismatches for Provoking Motion Sickness

Reason and Brand (46) suggest that most sickness-provoking sensory organ mismatches are of two types:

a. a visual-inertial mismatch, in which there is a conflict between incongruent sensory information from different sensory systems ("inertial" implies contribution from both vestibular receptors and other body mechanoreceptors); and

b. a semicircular canal-otolith mismatch, in which there is an incongruency of sensory information within the vestibular system itself.

2.3.1. The Vestibular Coriolis Effect -- A Semicircular Canal - Otolith Mismatch

The so-called vestibular Coriolis reaction is a mismatch involving the semicircular canals which causes particularly unpleasant sensations that are highly provocative of motion sickness. It is relevant to describe the Coriolis reaction because of its importance to many types of real-life incidents of motion sickness; for example, in seasickness, air sickness and car sickness.

In rotating an upright subject about an Earth-vertical axis, the horizontal semicircular canals (see Figure 3b) are stimulated during the initial accelerative phase of the rotation. After constant velocity rotation has been achieved, the horizontal canals cease to signal a turning motion. If the head is tilted forward at this time, the brain has to integrate several conflicting signals. The horizontal canals, which have been taken out of the plane of rotation, now signal a decelerative force. The four vertical semicircular canals (see Figure 3b) which have been brought into the plane of rotation, signal accelerative forces. The end result is an illusory sensation of turning -- the Coriolis effect -- which is perpendicular to both the head-tilt axis and the Earth-vertical axis of rotation. Nausea results from the mismatch between the canal inputs (which signal an untrue head tilt) and inputs from otoliths and other body mechanoreceptors (which signal the true head inclination). (The eyes need not be open during this procedure.)

2.3.2. The Pseudo-Coriolis Effect

If the head is tilted down or onto the shoulders during conditions of circular vection about an Earth-vertical axis, then the

.../10

sensations, though qualitatively weaker, are analogous to those experienced with the vestibular Coriolis reaction. These sensations result from a so-called pseudo-Coriolis effect, and are important in understanding sensory organ mismatches in motion-like sicknesses such as simulator sickness and cinerama sickness.

2.4. Neurosensory Mismatches Associated with Typical Forms of Motion Sickness

As long as Man moves about actively on land, walking and running, his brain normally receives all kinds of correlated sensory information that are perceived and integrated in memory stores, as appropriate, for good spatial orientation. However, when Man is moved about passively by ship, by car, or otherwise so that the dynamic range of the vestibular receptors is exceeded (and false information is transmitted to the brain); or if man is exposed to new or different motion environments, then the brain, becoming conscious of the discrepancies within its memory stores, is unable to integrate the information into an unequivocal motion perception and orientation. In severe cases, the result is complete disorientation, concomitant with the onset of motion sickness.

To understand the nature of these neurosensory mismatches in terms of their occurrence in TEMPSC, it is important to make comparisons to other mismatches that are associated with several types of motion sickness; namely, car, sea, air, simulator and Space sickness (5,46).

2.4.1. Car Sickness

It is well known that car drivers do not often get car sick; passengers adjacent to the driver may be affected; and those in the rear seats are most likely to become sick. Reason and Brand (46) cite a case of a man becoming sick when riding in a coach with his back to the horses. It is also known that reading a map or other documents while being driven along a winding, bumpy road is an invitation to motion sickness.

In terms of the neurosensory mismatch concept, it follows that the driver actively initiates the movement of the vehicle, he has a good external visual reference, and his visual information agrees with his vestibular information as well as with the mechanoreceptive information provided by the seat and seat-back pressures. The front seat passenger also has good visual, vestibular and mechanoreceptive information; and, if he so chooses, can "co-drive" the vehicle. (Experienced street car conductors tend to "move along with the vehicle" during starts and stops; and, in this way, alleviate any tendency towards motion sickness.) Rear seat passengers are not able to actively "co-participate" in the driving, and, therefore, do not have any set pattern of expectation. Their visual information is mainly confined to the inside of the car, which is stationary. This is even more apparent in night time driving or when reading with the head down. Independent head movements made during turns can also provoke Coriolis reactions

.../11

in passengers. However, drivers are less likely to make such independent head movements because their concentration is more focussed on driving the car.

The neurosensory mismatch concept suggests that a rider facing backwards has an external visual reference that is quite different from a front seat passenger's pattern of expectation of vehicular motion. Reason and Brand (46) indicate that the relative incidence of motion sickness in front, rear, and sideways-facing seats has not been determined. However, they suggest that common experience indicates that facing forward is the least nauseogenic. There is some evidence that, by shutting the eyes, one can remove the conflicting visual information created by the stationary interior of the vehicle. However, the best visual strategy is to view the distant horizon straight ahead, so that visual and inertial inputs of motion do not conflict (36).

2.4.2. Seasickness

Watching waves over the side of a ship in moderate-to-rough seas is considered to be nauseogenic because the movement of the ship cannot be correlated with the apparently random motion of the waves. Experience has shown that seasickness is least likely to occur when the passenger is on deck and able to view the horizon, or, better still, some nearby fixed landmark. Standing in the bow of the ship and getting a "feel" for the ship motion is also known to be beneficial in preventing seasickness. When the degree of ship movement is moderate, visual, vestibular and other inertial information can be congruently registered by such actions by the passengers.

When the sea becomes rough, the total range of ship motion cannot be observed or anticipated. The horizon can disappear behind the waves and provide a misleading visual cue that, in itself, is nauseogenic.

During ship motion, a neurosensory mismatch between the otoliths and the semicircular canals occurs, regardless of whether or not the visual cues are appropriate. Whenever the otoliths sense an apparent cyclic change in gravity, as is the case during up-and-down ship motion, the memory stores associate this with a synchronized rotation. However, the expectation of rotation is not fulfilled, and a canal-otolith conflict is the result (4,45).

Remaining below deck in a ship's cabin in which the view is largely restricted to the closely-confined stationary walls, creates a neurosensory mismatch between the eyes and the vestibular system that can cause nausea. Moreover, independent head movements which are superimposed on the motions of the ship may induce Coriolis-like sensations. Recent work has shown a correlation between spontaneous head movement and motion sickness in simulated rough water exercises of a surface effect ship (1). Additionally, ship's passengers are not actively co-drivers; they move passively with the ship's motion; and, accordingly, their patterns of expectation are seriously compromised.

.../12

Claremont (11) advises that, to prevent seasickness below deck, it is necessary to take a number of constructive actions. First, one should lie flat on the back to limit independent head motions. (It follows that lying supine with feet pointing aft also places the head and body in a position in which the patterns of expectation in the memory stores triggered by the otoliths will more closely resemble those of the normal locomotions of walking and running,or riding on a backyard swing.) The eyes should be closed to remove the conflicting visual cues. It is necessary to lie perfectly still and minimize body contact points in order to reduce conflict between the vestibular and other mechanoreceptive systems. Finally, one must concentrate on the rhythm of the ship's movement so that the patterns of expectation can be more fully met.

2.4.3. Air Sickness

The motion environments of pitch, roll and yaw, and the pulling of positive and negative G's during the maneuvering of high performance aircraft are particularly conducive to initiating motion sickness in student aircrew during their first few training flights (17). Trained pilots, once accustomed to the new environment, almost never become air sick while flying the aircraft. However, they may become sick as co-pilots or passengers when they are unable to co-drive the aircraft. Crew members, such as navigators or weapon system operators, are more prone to air sickness than pilots. They are usually confined in a small enclosed space, and must monitor and/or activate in-flight equipment with a severely restricted view of the outside visual world. At the same time, they may also be subjected to a variety of accelerative forces, for example, during turbulent weather, low-level terrain-following flights, or high-acceleration combat maneuvering. The lack of perception of the true aircraft motion, combined with a restricted external visual reference, is a significant factor in initiating air-sickness by way of a "vestibular-visual conflict". However, there is also an intravestibular conflict, which is the main cause of air sickness. During prolonged constant angular velocity, whenever the pilot moves his head about while performing in-flight cockpit tasks, a Coriolis reaction occurs. This may be another reason why student pilots show a greater incidence of air sickness than experienced pilots; the latter have learned the importance of matching visual and vestibular signals as much as possible, and, therefore, deliberately limit their head movements during rolls or turns.

2.4.4. Simulator Sickness

For a flight simulator to be effective, it is necessary that it provoke visual and vestibular and other mechanoreceptive sensations in a manner similar to those which occur in real flight. Simulator sickness results when there is a mismatch in the dynamics of motion between the simulator and the real aircraft . A form of motion sickness, which can be induced by vection alone, is attributed to the absence of correlated vestibular and other mechanoreceptive inputs. This form of simulator sickness is experienced in fixed-base simulators. It is also the basis

.../13

of cinerama sickness, which occurs while watching wide-screen films taken from aeroplanes and other moving vehicles, and amusement park rides. Head motions, either in fixed-base simulators or while watching wide-screen films, can produce pseudo-Coriolis effects that contribute to the simulator sickness. The expectation of an accompanying real vehicular motion during a moving visual scene is overcome somewhat by resorting to a moving-base simulator containing a variety of vestibular and non-vestibular mechanoreceptive stimuli. Such moving-base simulators decrease simulator sickness to the extent that the different sensory cues are correlated. The importance of the concept of a pattern of expectation to the neurosensory mismatch construct of motion sickness is borne out by the fact that, in most simulators, experienced pilots are much more prone to simulator sickness than are student pilots. Reason and Brand (46) cite the example of a film made from a moving car going down a winding mountain road; everyone watching it became sick. When the film was run backwards, none of the viewers became ill! Again, the importance of expectation is demonstrated.

2.4.5. Space Sickness

Space sickness has occurred in 50% of those people who have flown in Space (4). It appears to be invoked by head movements made in the Space environment of microgravity. Its signs and symptoms are similar to those of seasickness. Most astronauts adapt to microgravity and are symptom-free in three to four days.

In the microgravity environment, the four otolithic organs (see Figure 3a) do not respond to head tilt; they only react to linear accelerations. Therefore, the pattern that the brain perceives from head movements is totally unfamiliar to that expected on Earth. Given the fact that other proprioceptive and even visual cues become ambiguous under the influence of microgravity, it is not surprising that mismatch conditions for motion sickness are present.

2.5. Neurosensory Mismatch Conditions Specific to TEMPSC

The typical TEMPSC is a highly-visible orange lifeboat, which is self-righting and made of a fire retardant, glass fibre-reinforced plastic (Figure 4). Offshore drilling rigs are required by regulation to use TEMPSCs because they provide a relatively safe environment against the cold Canadian waters, and the danger of exposure to fire or toxic gases while evacuating the oil rig.

TEMPSCs vary in seating capacity, carrying anywhere from 14 (Whittaker CA 14) to 75 (Watercraft Mk III) persons. Table 1 gives some of the specifications of typical models currently being used by the oil industry. A series of doors or hatches that can be shut from inside provide access. TEMPSCs are designed with a limited number of portholes for occupant viewing of the exterior; for example, the Whittaker 50/54 has three very small portholes; others even fewer. A steering tower (wheelhouse) with several small windows allows the TEMPSC operator (coxswain) sufficient vision for maneuvering the lifeboat.

.../14

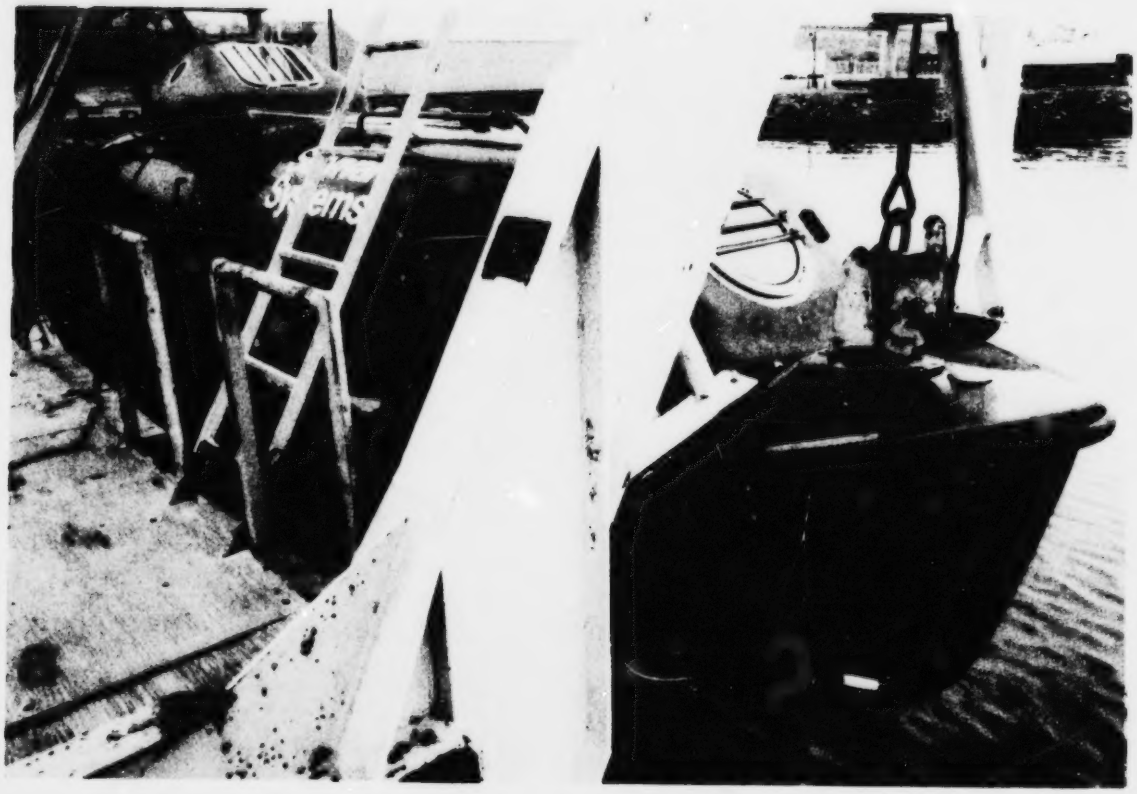

FIGURE 4 Representative TEMPSCs currently used on mobile offshore drilling units. Shown are: (a) a 48-man Watercraft in its hold-and-launch platform (courtesy of Albert P. Bohemier, Survival Systems) and (b) the CA 50/54 Whittaker during routine sea maneuvers (extracted from Whittaker Survival Systems Bulletin 50/54C).

.../14(b)

.../15

TABLE 1

TYPICAL TEMPSC SPECIFICATIONS

Make & Model	Capacity	Dimensions			Total Volume (m^3)
		Overall Length (m)	Overall Width (m)	Overall Height (m)	
Harding MCM 22	26	6.89	2.54	2.70	10.67
Harding Freefall FF34	40	10.52	2.95	3.55	26.89
Harding MCB 24	48	7.46	2.90	2.90	14.87
Harding MCM 60	60	8.61	3.16	3.20	21.32
Whittaker Survival Capsule	50/54	6.02	4.27	3.66	50.26*
Offshore Marine Engineering "Phoenix"	66	9.48	3.20	3.40	54.05*

* Estimated

.../16

It is evident that TEMPSCs were not designed specifically with the prevention of seasickness in mind. There are a number of neurosensory mismatch possibilities that are very potent inducers of motion sickness in TEMPSC occupants. First, the occupants are confined in a relatively-small enclosed shell (see Table 1) in which they have virtually no external visual reference. Accordingly, they act as passive passengers, with their vestibular organs signalling varied and sometimes intense motion while their eyes signal no motion at all. This neurosensory mismatch between the eyes and the vestibular apparatus was strikingly demonstrated in the case of the Rowan Gorilla I incident (see Appendix I). It seems that whenever the coxswain had to turn on the lights at night to read his panel gauges, several TEMPSC occupants immediately became nauseous. Better illumination of gauges would obviate the problem. Seven of the Rowan Gorilla survivors felt that the small size of the survival capsule contributed to their seasickness; four implicated the lack of windows as a factor.

Second, occupants sit upright in a variety of seating arrangements. In some Harding models, seating is arranged on longitudinal benches, with passengers facing each other, with their front or back directed outboard; that is, towards the TEMPSC's side. In the Whittaker survival capsule, the seating consists of two concentric rings of benches; in the 50/54 man capsule, passengers sit with their backs directed outboard; and in the Whittaker 34/38, the two rings of people face each other (see Figure I.1 in Appendix I). Some older TEMPSCs have bench seats for passengers to sit facing forward; it would appear that this would normally be the seating arrangement of choice during motor-powered or sea-anchor-directed forward motion if there was an associated good external visual reference. This is proven by the results of the Rowan Gorilla I incident, where three of the four coxswains did not get seasick (again, see Figure I.1 in Appendix I). Not only were they facing forward, but they also had good visual reference and were actively involved in steering the TEMPSC. (The remaining coxswain (#7) was very seasick wherever he sat.) Moreover, the three evacuees sitting directly across from the coxswain's position at the forward end of the craft were either only slightly unwell (#5) or did not get seasick. Even though their external vision was restricted, they, at least, were able to co-drive with the coxswain, and get the feel of the boat. Most of the other survivors were facing sideways in the 34/38-man Whittaker capsule; the majority were ill, <u>some dreadfully so</u>.

Lastly, much could be done to limit head and body movements in TEMPSCs so that the deleterious effects of the Coriolis reaction could be alleviated. Possibly, the worst condition for body restraint is to be found in those TEMPSC designs in which each occupant is secured to a bench seat by means of a simple lap belt without benefit of any back support. In some Harding models, each upright seat is provided with a four-point safety harness and a padded back and head support, which should reduce head and body motions substantially. In the 50/54 Whittaker capsule, personnel occupying the outer ring of seats can support their back and neck against the unpadded side wall of the TEMPSC. Those occupying the inner ring of seats must position their backs

.../17

against the legs of the outer-ring occupants in order to get even limited back support. Head support is difficult to obtain for these occupants. All occupants in the Whittaker capsule are restrained by means of a lap belt.

The authors noted that the best back and head support is found in the Harding Freefall TEMPSC. Occupants are supported in partly-moulded seats in recumbent positions with feet pointing either aft or forward depending on the model. Each seat is furnished with a shock absorbent polyurethane material to give comfort to the occupants and provide support to the sides and back of the body during transit. A lap belt, leg restraints and large headband secure the body and head to the seat. One improvement on this design would be to replace the head band with a good, padded head rest to restrict head movement. The head band could cause evacuees to choke on their own vomit if they are placed in a reclined position. Sixty-three percent of respondents from the Rowan Gorilla I incident reported that, given the choice, they would have preferred lying down to sitting upright in their TEMPSC.

Visual reference to the outside world could be provided in the design of future TEMPSCs by increasing the number of portholes, or by fabricating the domed top out of a safe transparent plastic material (non-distorting). In light seas, it is sufficient and safe to open the hatches to provide an outside view (for example, in the Ocean Odyssey incident). However, in rough seas, with wave heights up to 15 metres or more, in which the TEMPSC disappears into the waves (such as in the case of the Rowan Gorilla I), it would then be advantageous to reduce the external visual field. The visual cues provided by the turbulent waves would not necessarily be congruent with the motion experienced by the body mechanoreceptors, and, accordingly, might even increase the neurosensory mismatch experienced by the TEMPSC occupants over that experienced with limited cues. Additionally, the fear and anxiety that could be caused by observing such a harsh outside world could lead to panic. In this regard, it might be prudent to employ a retractable screen in future TEMPSC designs, so that visual reference to really bad sea conditions could be eliminated. Thus, the design requirements for reducing neurosensory mismatch would be twofold:

a. an open screen with full outside view for relatively good sea conditions; and

b. a closed screen for providing no external view during very bad sea conditions.

.../18

CHAPTER 3.

RELATIONSHIP BETWEEN SHIP MOTION AND SEASICKNESS

Environmental factors such as wind and waves cause ships and boats to move in unpredictable ways. The nature of ship motion is dependent on the size, shape and weight of the vessel. Studies by the Institute of Naval Medicine, Gosport, United Kingdom, indicate that the incidence of seasickness in Royal Navy ships varies from 15% to 66% and is inversely related to the size of the ship; that is, the smaller the vessel, the greater the incidence of seasickness (43). Consequently, the small size and flat bottom of the typical TEMPSC make it almost ideal for inducing seasickness in its occupants. Preliminary work at Robert Gordon's Institute of Technology, Offshore Survival Centre, Aberdeen, United Kingdom indicates that 21% of trainees became sick during TEMPSC exercises at sea for sea conditions having maximal wind speeds of 30-35 knots and wave heights at 1.5-2 m (I. Light and M. Greenen, personal communication).

Ship motion has traditionally been defined in terms of three translational (x-, y-, and z-) and three rotational (roll, pitch and yaw) components within a Cartesian coordinate system (see Figure 5). In a series of important studies, Lawther and Griffin (29-32) assessed the incidence of seasickness in more than 20,000 passengers from 114 voyages on 9 different passenger ferries around the British Isles in terms of these six motion components in different locations on the vessels. The passenger ferries consisted of 6 ships, 2 hovercraft and 1 hydrofoil. Measurements of motion were made using a series of accelerometers that were fixed rigidly to the vessels. The results explain why the TEMPSC is a provocative environment for motion sickness.

3.1. Frequency of Ship Motion

Lawther and Griffin (29,32) showed that ship oscillatory motion takes place over a frequency band from 0.1 to 0.5 Hz, with the dominant frequency occurring at about 0.2 Hz. In particular, motion in the heave or z-axis, and pitch occurred over a very narrow frequency band, between 0.1 and 0.3 Hz, with the peak energy centered at 0.2 Hz. The smallest ship studied had a slightly higher dominant frequency (0.25 Hz), which suggests that small ship size may be associated with somewhat higher motion frequencies.

Hovercraft motion was much more broad band in pitch and heave with most of the energy spread from 0.2 to about 1.0 Hz.

3.2. Ship Motion Acceleration Magnitudes

As expected, the magnitude of ship motion depends greatly on sea conditions. Moreover, heave acceleration magnitudes varied considerably with location along the length of the vessel. The variations in heave acceleration with ship location and frequency, as expressed in terms of

.../19

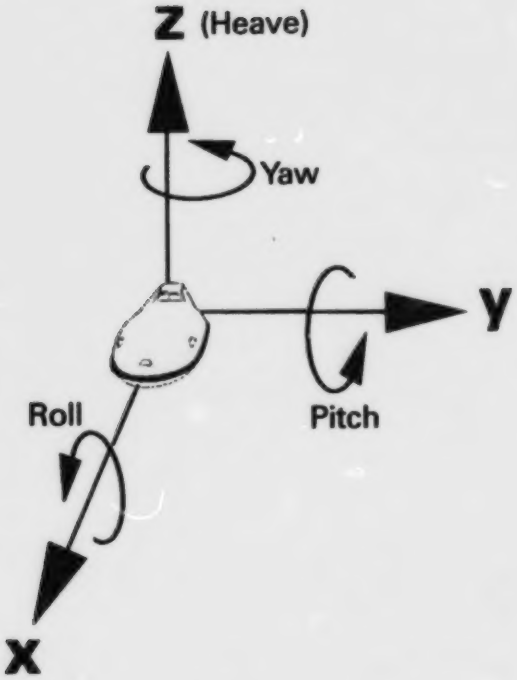

FIGURE 5 Cartesian coordinate system for describing TEMPSC motion. The z-, or heave, axis is the most important one for relating ship motion to seasickness.

.../20

power spectral density, are illustrated in Figure 6a for a typical ship, and in Figure 6b for a hovercraft. For ships, the minimal heave acceleration magnitudes occur near the centre of the ship and are confined to a narrow band of frequencies. The magnitudes at the bow are more than double those at the center and stern of the ship. Part of the contribution to the heave motion at the bow comes from the pitch component. In the hovercraft, the minimal motion occurred, for most of the frequency band of interest, near the stern. These differences between ship and hovercraft relate to the length-to-width ratio of the two vessels. This ratio is much smaller for the hovercraft, and, consequently, significant heave acceleration increases also occurred at the sides of the craft, where the passengers are located. Thus, in a fully-powered TEMPSC with sea anchor deployed, in order to reduce the deleterious effects of pitch motion, occupants should first fill the inner ring of seats near the coxswain's position. This procedure would allow those occupants who are more prone to seasickness and the injured to be placed in more favourable positions. One finding of this study was that those who felt "absolutely dreadful" in the Rowan Gorilla I incident, all occupied the outer ring of TEMPSC seats (see Figure I.1 in Appendix I).

3.3. Relating Heave Motion to Seasickness

The occurrence of motion sickness and the associated vomiting are approximately linearly related to the magnitude of the z-axis acceleration experienced (32). A three-dimensional representation of the incidence of motion sickness as a function of both ship frequency and acceleration magnitude is shown in Figure 7 for 2 hours of exposure to vertical periodic motions (4,41). Motion sickness is greatest at a heave frequency of 0.167 Hz; as frequency increases beyond about 0.5 Hz, the ability to tolerate the motion without becoming sick increases. Beyond a frequency of about 1 Hz and an acceleration above 1 g (1 g = 9.8 m/s^2), motion sickness becomes secondary to the other physiological problems encountered. This observation is consistent with that of at least one of the survivors of Rowan Gorilla I. He indicated that the most nauseogenic situation occurred around the time of rescue, when the ship motion frequency and heave amplitude had decreased considerably from that encountered at the time of abandonment. Likewise, in the Ocean Odyssey incident, waves were only about 1 m high, yet 75% of TEMPSC occupants were seasick. The higher frequency motion in hovercraft (about 0.6 Hz) was found to be less nauseogenic than similar heave magnitudes at lower frequencies (32).

How do these findings fit into the neurosensory mismatch construct? Benson (4) has indicated that, for frequencies less than 0.5 Hz, there is a phase error between the heave motion transduced by the otoliths and the forces signalled by the other mechanoreceptors and visual sensors. When this is combined with the synchronized rotation that is signalled as a result of the intravestibular conflict to heave motion, the conditions for motion sickness are prevalent.

.../21

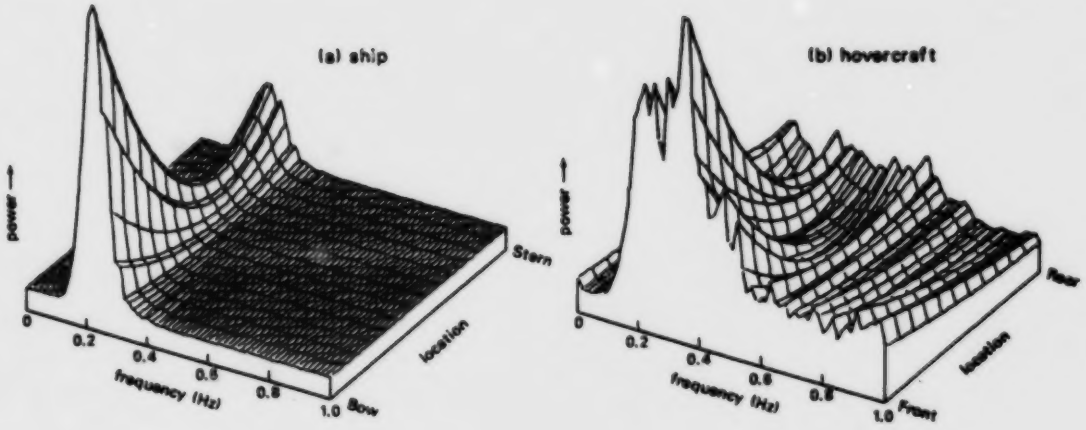

FIGURE 6 Illustration by means of power spectral density, of the variation in heave acceleration with location in: (a) a ship, and (b) a hovercraft (from Lawther and Griffin (32)).

.../22

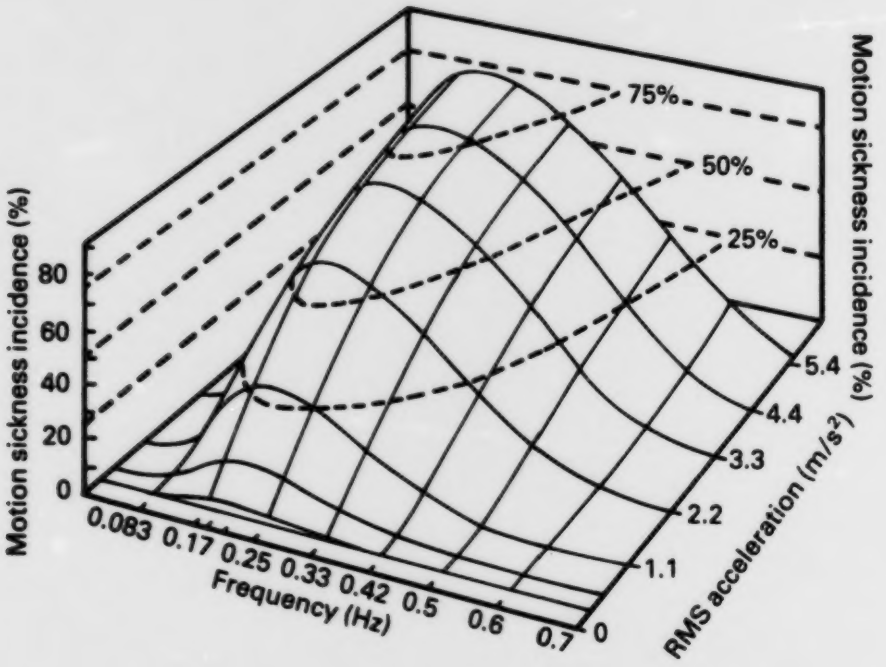

FIGURE 7 Incidence of motion sickness as a function of frequency and acceleration for 2 hours exposure to z-axis sinusoidal accelerations. The boundaries for 25, 50, and 75% incidence of motion sickness are also shown (dashed lines) (from O'Hanlon and McCauley, (41)).

.../23

The duration of heave motion also has an effect on seasickness. For durations from one-half to about six hours, Lawther and Griffin (32) found an increased incidence of seasickness with increasing duration of exposure. (For longer durations than these, the confounding effects of adaptation in reducing seasickness also would have to be considered.)

Limiting criteria in the form of severe discomfort boundaries for vertical accelerations associated with motion sickness have been determined by the International Standardization Organization (ISO 2631/3 - 1985 (25)). These are illustrated in Figure 8 as a function of frequency for exposure times of 30 minutes, 2 hours and (tentatively) 8 hours. Above each of these boundaries, passengers not familiar with ship motion experience severe discomfort after the exposure times indicated. Also shown is a limiting curve taken from McCauley and colleagues (35), above which there is a 10% chance of vomiting due to motion sickness amongst unadapted healthy men. The frequency response for normal locomotion (running and/or walking) is indicated for comparison (16). Note that the curve for walking/running lies well outside the frequency and acceleration limits for 10% vomiting and the other discomfort criteria.

The frequency and acceleration of TEMPSC motion have significant bearing on passenger comfort. It is important to consider these factors in TEMPSC design and operation for conditions both under power, and with and without sea anchor deployment. However, given the fact that the TEMPSC displaces relatively little water, and its motion is similar to that of a free floating particle that bobs up and down according to the whims of the waves, it is probable that very little can be done to the TEMPSC as a whole to alleviate the conditions that predispose one to seasickness. Moreover, since heave accelerations greater than 1 m/s^2 are commonly reached or surpassed in a TEMPSC, it is unlikely that overall design improvements will have any significant outcome with respect to seasickness.

.../24

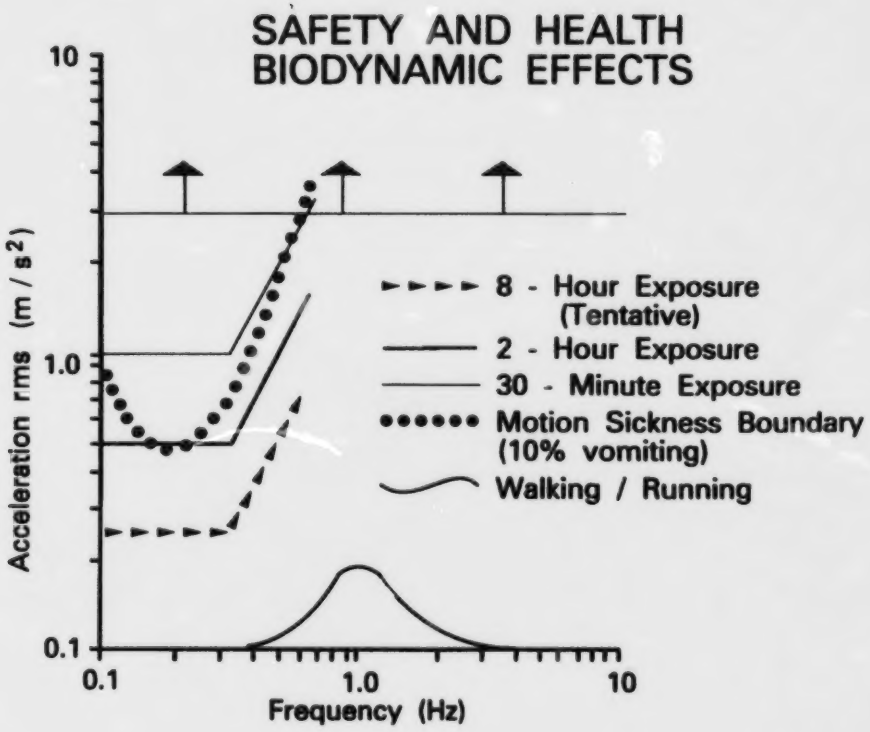

FIGURE 8 Illustration of the severe discomfort boundaries for frequencies 0.10 to 0.67 Hz for z-axis accelerations for three different exposure times (from ISO 2631/3-1985 (25)), the limiting curve corresponding to a 10% chance of vomiting from motion sickness (from McCauley et al., (35)), and the frequency response for normal walking and running (from Frank et al., (16)).

.../25

CHAPTER 4.

REVIEW OF SEASICKNESS IN MARINE DISASTERS

The statement of work requested a literature search, as well as a review of reports of relevant marine accidents or incidents, with the objective of determining whether or not prolonged exposure to seasickness endangers the lives of TEMPSC occupants.

4.1. Literature Review Pertaining to Survival-at-Sea

The current most comprehensive treatise on our understanding of survival-at-sea is the document which Smith (53) prepared for the Survival-At-Sea Subcommittee of the Royal Navy Personnel Research Committee of the Medical Research Council. It covers research conducted predominantly in Great Britain, between 1940 and 1975, on saving lives after encountering an accident at sea.

Post war research had indicated that "... between 30,000 and 40,000 officers and men, or two thirds of the naval losses for the whole war, probably lost their lives by being drowned." It was quite clear that too many men "... died after reaching temporary support in the sea ...", and that not enough attention was being paid to saving them under such conditions. This awareness led to the development of some important life-saving equipment such as the inflatable covered liferaft,the various designs of survival suits that protect against hypothermia, and the life jackets that are currently used in civilian and military marine operations.

Physiological work on survival-at-sea by the Subcommittee was considered in terms of four main phases. To quote Smith (53), those were: "... first, the prevention of hypothermia which can kill in about an hour; second, the prevention of seasickness which, if allowed to continue, can cause dehydration, facilitate hypothermia and destroy morale; third, the avoidance of death from dehydration which, with adequate protection from the climate, should only become serious after a matter of days; and fourth, the prevention of death from starvation which is unlikely to happen for some weeks." Thus, severe and repeated vomiting through seasickness is a hazard to survival-at-sea, because it can lead to dehydration and loss of body electrolytes, which can cause a breakdown in morale, loss of interest in everything (including the ability to participate and cooperate in rescue attempts), and a predisposition to hypothermia (4,53). In his comprehensive review of motion sickness, Money (36) cited a study which related that death through seasickness in liferaft occupants is probably contributed to, and hastened, by dehydration.

Reason and Brand (46) commented that it was possible to differentiate between seasickness in peacetime, when it is seldom a threat, and its presence in wartime. (This likely refers to the fact that, in peacetime, search and rescue efforts are more easily mustered than in times of war.) During war, the rapid movement of large numbers of

.../26

personnel is often required. Small craft such as liferafts and amphibious landing craft may be used, often in unsuitable sea conditions. Under these circumstances, the debilitating effects of seasickness can constitute a major hazard both to the success of the operation and to the lives of those involved.

No review on the incidence of seasickness in the Canadian Navy has been written, but the general opinion is that it is inherent to the job and not a life-threatening hazard. There have been cases in which individuals never adapted to ship motion and, subsequently, changed occupations. Each year, 10 to 20 sailors fall into that category.

4.2. Canadian Coast Guard Reports

The Canadian Coast Guard is the regulatory authority for all ships operating in Canadian waters. In the event of an accident involving commercial vessels in Canadian waters, or Canadian vessels in international waters anywhere in the world, the Canadian Coast Guard, and, more specifically, Transport Canada's Marine Casualty Investigations (MCI), is called upon to conduct the preliminary inquiry. The majority of incidents investigated by MCI involve commercial fishing vessels under 55 gross metric tons, although larger vessels (such as oil tankers over 3,500 gross metric tons) are also included. The large percentage of inquiries concerning fishing vessels reflects the fact that Canada has a fishing fleet of approximately 41,000 vessels. The number of work-related fatalities within the fishing industry is, on average, 28 persons per year (12).

An in-depth search of 14,196 of MCI's preliminary inquires from 1976 onwards was carried out with a review of all accidents involving lifeboats and liferafts; in total, some 100 reports were investigated. The nature of the ship incidents ranged from those caused by shifting deck cargo, grounding and flooding of the fish holds, to those resulting from fire, capsizing and sinking.

Among the significant abandonments that took place with subsequent entry, or attempted entry, into lifeboats or inflatable rafts, a total of 271 people were rescued safely, and 33 deaths were noted. Abandonment in rough seas with high winds and waves was common to several cases. The causes of death reported were drowning, loss at sea, burning, suffocation and hypothermia; no evidence of death due to seasickness was found. Whether or not seasickness contributed to any of the cases of hypothermia is simply not known, nor can it be postulated.

4.3. A Review of Some Marine Disasters in the United Kingdom

A visit was made to the Royal Navy Institute of Naval Medicine, Gosport, to examine their collection of naval incidents (compiled from National Press clippings for the year 1974). The clippings included all incidents worldwide in which British lives were involved in ships; and all incidents in waters contiguous to the United Kingdom, regardless of the nationalities involved. They were classified into incidents

.../27

involving survival-at-sea in ships and liferafts, and incidents of immersion in which liferafts or other craft were not involved. Although drownings and near drownings, death after rescue, hypothermic deaths and other causes of death were cited, there was no mention made of any loss of life due to seasickness.

There is some anecdotal evidence of a case of the near-death of a sailor in which seasickness was a contributory factor in the rupturing of the esophagus due to constant retching with excessive blood loss (Mallory-Weiss Syndrome). Otherwise, there do not appear to be any hard facts regarding death through seasickness.

4.4. Incidents Involving TEMPSC Occupants

With the advent of the TEMPSC as the principal means for survival from Mobile Offshore Drilling Units (MODU's), there have been many reports of severe seasickness. In the following sub-sections, the extent of the seasickness in TEMPSC occupants is discussed in five major oil rig disasters; in chronological order of occurrence, these are the Alexander L. Kielland, Ocean Ranger, Vinland, Ocean Odyssey, and Rowan Gorilla I incidents.

4.4.1. Alexander L. Kielland Disaster

The accomodation platform, Alexander L. Kielland, a mobile semi-submersible unit, lay at anchor in the Ekofisk field in the North Sea when it collapsed and capsized on March 27, 1980, between 1830 and 1850 hours Greenwich Mean Time. The location of the unit was: latitude 56° 28' N; longitude 3° 6' E; 280 km from the Norwegian coast. Weather and sea conditions at the time of the accident were severe: poor visibility, strong winds up to 39 knots, 6 to 10 m waves, and temperatures of 4-5°C (water) and 4-6°C (air). Methods of abandonment varied from TEMPSC and liferaft evacuation to direct entry into the sea. Of 212 men aboard the Alexander L. Kielland, only 89 were rescued. The main cause of death was due to drowning and hypothermia (7,40). There was no indication that seasickness contributed to any of these deaths.

The launching of the TEMPSCs during the rig abandonment was a complete debacle. Four of the five 50-man "Harding Safety" type 26 MC TEMPSCs, which made it to the water, were subsequently smashed against the platform because of problems in releasing the lifeboat hooks under load (see Figure 9 for examples of these damaged TEMPSCs). One of the boats (#1) had its wheelhouse crushed, which made it possible to release the aft hook by hand through the opening created by the impact. (Someone had succeeded in releasing the forward hook earlier.) The fifth TEMPSC (#5) fell into the water upside down, but those inside and others in the water managed to right it!

The #1 TEMPSC, containing 26 men, had its people rescued by helicopter on March 28 between 0130 and 0500 hours. During rescue, there were a few signs of panic but these were quickly brought under control

.../28

FIGURE 9 Three views of severely damaged TEMPSCs from the Alexander L. Kielland diaster; illustrating: (a) damaged wheelhouse (arrow), (b) TEMPSC devoid of dome, and (c) hole in bow (courtesy of P. Werenskiold, Norwegian Marine Technology Research Institute).

.../28(b)

.../29

(39). The #5 TEMPSC after launching held 14 occupants, but later picked up another 19 survivors from the sea. Rescue was twofold; some of them were rescued by helicopter; the remainder by supply vessel. Most occupants in both #1 and #5 TEMPSCs suffered from hypothermia and seasickness at the time of rescue. Moreover, none of the survivors likely took any medication against seasickness (40).

It must be remembered that the use of survival suits as lifesaving equipment was not regulated at the time of the Alexander Kielland disaster. However, the relatively short time (20 minutes or so) for abandonment under conditions of crisis might have prevented donning the suits in any event.

Lack of safety training was considered to be a factor in reducing the chance of survival. However, the report of the investigative commission into the disaster concludes that experience at sea is a more important factor for survival than the safety training that was then required by regulation (14,39).

4.4.2. Ocean Ranger Disaster

The loss of the Ocean Ranger, a semi-submersible drilling unit, and its entire complement of 84 men was precipitated by a chain of events that started with a severe winter storm which passed over the area on February 15, 1982. Ocean Ranger was located at: latitude 46° 51' N; longitude 48° 50' W; 325 km east of St. John's, Newfoundland (on the Grand Banks). The weather at the time of the disaster was forecast as winds of 75 knots gusting to 90 knots, and significant wave heights of 7.5 to 10 m, with maximal wave heights of 13 to 18 m. Water temperature at the time was -1°C.

The storm caused seawater to break and enter port lights in the ballast control room, causing an electrical malfunction on the ballast control panel, which made the rig list towards the bow and into the wind and the waves. The crew's subsequent failure to follow proper operational procedures led to the flooding of the forward ballast tanks and chain lockers, increasing the list and, eventually, causing the rig to capsize and sink.

It has been estimated that the rig was abandoned around 0130 hours local time. One of the lifeboats, a 50-man Harding TEMPSC was spotted by the Seaforth Highlander, the standby vessel, at 0150 hours. The TEMPSC was under power, and both it and the Seaforth Highlander maneuvered into position to effect a rescue mission. The TEMPSC was riding low in the water, and it was badly damaged with holes on both sides of the bow from the waterline to the gunwale. Men were spotted bailing water. At that time, the swell exceeded 18 m, and there were 4.5 m breaking waves.

At 0232 hours, the TEMPSC was reported to be alongside the standby vessel. While life-ring lines were being fastened, seven or eight men emerged from the lifeboat and stood on the port gunwale; that is,

.../30

on the side away from the standby vessel. The TEMPSC began to roll over away from the Seaforth Highlander and capsized, throwing the men standing on the gunwale into the water and snapping the lines. Attempts to rescue the men from the water failed; they appeared to become unconscious very quickly. At 0700 hours, another supply vessel found the overturned TEMPSC and attempted its recovery. Several bodies floated through a hole in the bow and some 20 bodies were observed to be strapped in by seatbelts. This TEMPSC, which held over 30 men, was never recovered.

Search and rescue operations eventually led to the recovery of 22 bodies, two of which were found in a liferaft. The cause of death was drowning while in a hypothermic condition. The lack of survival suits available to the crew on the Ocean Ranger contributed to their deaths. It is impossible to establish whether or not the Ocean Ranger "riggers" became seasick. It could be argued, however, that they were not in the water long enough to get that seasick to cause death.

The capsizing and sinking of the Ocean Ranger with all lives lost was a tragedy that was widely felt within the Canadian offshore oil industry; as a result, a Royal Commission was established. Its terms of reference included, in part, the investigation into all aspects of safety of life at sea and making recommendations regarding practices and procedures that should be followed in effecting safe drilling operations in the Canadian offshore oil industry (48,49). COGLA subsequently issued a directive requesting that all drilling units have sufficient survival suits for 200% of the crew.

4.4.3. Vinland (Uniacke G-72) Incident

The gas well, Uniacke G-72, which was drilled with the semi-submersible drilling rig, Vinland, was located at latitude 44° 11.5' N and longitude 59° 41' W (20 km north-east of the western end of Sable Island in the Scotian Shelf). At 2202 hours Atlantic Standard Time, 22 February 1984, the Vinland experienced a "blowout" and lost all of its main power. At 2252 hours, the crew of 75 men and 1 woman completed their evacuation of the rig, with 35 and 41 persons, respectively, in each of two 50-man "Harding Safety" type MCR TEMPSCs. The weather at the time of abandonment was reported to be: winds at 25-30 knots, significant wave height at 2.4-2.8 m, three-hour maximal wave height at 3.7-4.6 m, air temperature at -3°C, and sea temperature at +1°C. Because of these weather conditions, no attempt was made to transfer the survivors to the rescue supply vessels that were escorting the two TEMPSCs.

All crew members boarded the TEMPSCs wearing fully-zippered Norwegian NORD-15 survival suits. The survivors found that, in some instances, the suits kept them too warm. Seating arrangements provided for fore and aft, and side-to-side (athwartship) occupancy, with safety harness belts available for each person. All occupants were seasick at one time or another before rescue. A report by the Norwegian Maritime Directorate considered seasickness the greatest problem because the

.../31

survivors became fatigued and dehydrated; and, as a result, indecisive in their deliberations (59).

Two hours after abandonment, the decision was made to head for the lee of Sable Island. Although all TEMPSC occupants had been issued the anti-seasickness drug, Pestafen (meclozine) at the time of abandonment, it proved to be ineffective;90% of the survivors (including the woman) were "... violently seasick ..." by the time the decision was made to head for Sable Island. Those who were not initially seasick had eventually been overcome by the "... pervasive atmosphere in the boats" and became seasick.

A convoy of three supply ships escorted the two TEMPSCs to Sable Island. During transit, one of the men suffered an apparent heart attack. Between 0650 and 0715 hours, 23 February 1984, some 8 hours after abandoning the drilling rig, with the two TEMPSCs within 2 km of Sable Island, all survivors were transferred to the supply vessels escorting them.

In a telephone conversation with one of the survivors and, from other reports, it was revealed that most individuals became seasick within one-half to one hour (and some within 15 minutes) of launching the TEMPSC. As soon as one person vomited, a chain reaction started, with the others becoming nauseous, then commencing to vomit. Although there was adequate ventilation, it was still uncomfortably warm within the survival suits; and most unzipped them. It was "smelly" from vomit and "sweaty" inside the TEMPSC. The survivor contacted by phone had felt dehydrated and somewhat weakened, but felt that he had had good motor ability and mental attitude at the time of rescue. He felt that had the accident occurred in summer, then there could have been more serious problems with dehydration and heat stress resulting from the hot TEMPSC environment.

By the time of the transfer, the seasickness had subsided. The top and side hatches of the TEMPSC had been opened, and the survivors' spirits were much improved. During transfer, the survivors were able to climb scrambling nets unaided on to the rescue vessels. Other than mild shock and seasickness, there were no injuries to the survivors. The weather in the lee of Sable Island was good at the time of the rescue and the height of the waves was about 2 m or less, according to the survivor interviewed.

The heart attack victim was airlifted by helicopter to Halifax, and was pronounced dead on arrival at the hospital. A post-mortem examination indicated that death resulted from a heart attack. The stress involved in evacuating a drilling rig under hazardous conditions likely contributed to the attack. It was considered beyond the scope of this work to investigate if there were any further predisposing familial or personal cardiac risk factors in this unfortunate person.

The reports of the investigation (8,47) cite the effectiveness of the training program on board the Vinland, and the good leadership

.../32

exhibited by senior personnel as being responsible for the orderly manner and good conduct displayed during the evacuation and rescue operations. The report by the Norwegian Maritime Directorate contends that staying in the TEMPSCs until calmer waters were reached at Sable Island was the right decision (59).

4.4.4. Ocean Odyssey Incident

On 22 September 1988, at 1156 hours Greenwich Mean Time, an uncontrollable fire occurred on board the semi-submersible drilling rig, Ocean Odyssey. The Ocean Odyssey's location was: latitude 57° 2' N; longitude 1° 56' E; some 130 km due east of Aberdeen, United Kingdom. Weather and sea conditions at the time of the fire alarm, and until the evacuees were safely ensconced some 4 hours later, were similar: good visibility, winds at 10 to 20 knots, and waves 1 m high. Seasonal averages for air and water temperatures in the area are 19°C and 11°C, respectively.

Preliminary indications are that, following the fire alarm, 54 riggers entered and remained in two 58-man Watercraft Mark II TEMPSCs waiting for the call to abandon the MODU. Approximately one hour later, the Ocean Odyssey suffered an explosion. Of the remaining 13 men who continued to perform essential services on the rig, 4 came on board the TEMPSCs, 8 jumped into the sea and 1 died on board. The 58 men in the two TEMPSCs successfully abandoned the rig.

A Zodiac® rescue craft picked up the eight survivors from the sea within 10 minutes. The fifty-eight evacuees in the TEMPSCs were rescued within 30 minutes. In all instances, rescue transfer was first to the standby vessel, then by helicopter to another semi-submersible platform. The evacuees spent about two hours on the standby vessel.

Dr. I. M. Light and Capt. M.G. Greenen, Offshore Survival Centre, Robert Gordon's Institute of Technology, Aberdeen, United Kingdom conducted a survey of the incidence of seasickness in the Ocean Odyssey survivors. A questionnaire was sent by mail to each rigger. A summary of the results are as follows:

Of the 40 personnel who replied to the questionnaire, 75% were seasick; 68% within the half hour between rig evacuation and rescue transfer of TEMPSC occupants to the standby vessel. (These figures also include responses from evacuees who were rescued by the Zodiac®, and take into account the fact that the onset of motion sickness, in some instances, only occurred later, on the standby vessel.) At first glance, this may appear to be a higher proportion than one might expect considering the relatively benign weather and sea conditions that prevailed during the time these survivors were at sea. In fact, 60% of the respondents did not consider themselves prone to seasickness. However, it does illustrate the important fact that small, essentially flat-bottomed vessels, such as a TEMPSC, provide a very provocative, nauseogenic environment for their occupants.

.../33

Only 9 respondents reported having taken any antimotion sickness drugs; likely, this took place on the standby vessel and not in the TEMPSCs. In any case, 65% of evacuees vomited; so, regardless when the antimotion sickness medication was taken, it had no effect. Heat was considered a contributory factor in their illness by 40% of TEMPSC occupants; diesel fumes by 45% and apprehension by 33%. The men wore big, bulky neoprene suits, which they had to remove as some of them became faint from the extreme heat within the TEMPSCs. All survivors commented on how nauseogenic it was when another person vomited. The inability to see the horizon was also cited as a factor. All the provocative criteria to produce seasickness were essentially there and did just that!

4.4.5. Rowan Gorilla I Incident

The jack-up oil rig, Rowan Gorilla I, was being towed from Halifax to the North Sea by the tug, Smit London, when it encountered heavy seas. At 0120 hours Atlantic Standard Time, 15 December 1988, the towline broke and the Rowan Gorilla I, after taking on water, began to list badly. Twenty-five men and two women changed into survival suits, and entered a Whittaker 34/38-man survival capsule. The capsule was lowered into the sea at 1245 hours, 15 December. The location of the oil rig was: latitude 40° 04' N; longitude 53° 09' W; 1000 km east of Shelburne, Nova Scotia (in the Gulf Stream). Seas were reported to be from 12 to 15 m high, with winds at 50 knots. The water temperature was 17°C; the air temperature 15°C.

The survival capsule had diesel fuel for 24 hours. However, the engine overheated 40 minutes after the rig was abandoned and was shut down. Because of the severe sea conditions, the coxswain did not deploy the sea anchor. He found that the capsule handled itself well, and he did not try to restart the engine. Although the capsule never overturned, it was swamped at times.

The survivors remained in the capsule for just over 22 hours. The Smit London, which stood by the entire time, launched a Zodiac® rescue craft to recover the survivors on the morning of 16 December 1988. Recovery of all 27 personnel was completed by 1057 hours. Waves at the time of rescue were 3.7 to 4.6 m high, and the wind speed was 30 to 35 knots.

On 16 January 1989, a visit was paid to COGLA, Halifax, to administer a motion sickness questionnaire to the survivors of Rowan Gorilla I. (The questionnaire was modified from versions developed by Lawther and Griffin (29), and Light and Greenen, Robert Gordon's Institute of Technology.) Twenty-one questionnaires were completed on site; three others were later received by mail. The composite results of the survey are included as Appendix I to this report.

Of the 27 survivors, only 6 did not get seasick, including the 2 women. Of the 24 who replied to the questionnaire 77% became seasick; 25% did not vomit; 50% vomited within half an hour (one within 2 minutes

.../34

of launching the TEMPSC), with the remainder vomiting one hour or more after abandoning the rig. Sixty-seven percent of the survivors answering the questionnaire felt that they were becoming less sick as time went on; that is, they felt that they were adapting to the sea motion. Fifty-eight percent felt that their sickness was caused by someone else vomiting.

Eighty-three percent indicated that it was hot and stuffy inside the survival capsule; 63% said it was "sweaty". At the time of rescue, 29% were seasick, 8% were vomiting, 48% were sweating and 48% felt they were dehydrated. Almost all felt that they had had good motor ability, physical strength and mental attitude at the time of recovery. Ninety-six percent had taken anti-seasickness drugs at the time of evacuation; most by tablet, some more than once. A variety of drugs were taken: Gravol (dimenhydrinate) oral tablets and/or suppositories, Bonamine (meclozine) oral tablets and/or the transdermal scopolamine patch administered behind the ear. They were ineffective, as 62.5% of those answering the questionnaire were sick within half an hour of launching the TEMPSC. The short time between application of drug and experiencing sea motion was the major contributing factor causing the poor results.

All respondents to the questionnaire had taken survival training, which included familiarization with seasickness. In fact, the organization which conducted the training, Survival Systems International, insists upon having its trainees experience some seasickness, if possible, as part of the psychological conditioning process for overcoming their fear of the unknown sea (A.P. Bohemier, personal communication). Trainees are put into liferafts for an hour or more in sea conditions with waves up to 8 m high and winds up to 40 knots. Up to 90% of trainees experience seasickness under such extreme sea conditions; on the average, 60% become seasick under more moderate conditions. Fifty percent of the survivors of the Rowan Gorilla I were of the opinion that their training with Survival Systems was the single most important factor that led to their survival; 38% attributed it to team work. Twenty-four of the survivors were from Nova Scotia; all had known each other for some time and all considered themselves as part of a family unit that helped and took care of each other. This also contributed to their survival.

4.5. Commentary on Seasickness Endangering Life in TEMPSC

Table 2 summarizes some important aspects of the five drilling rig incidents that relate to the purpose of this study; namely, whether or not prolonged exposure to seasickness endangers the lives of TEMPSC occupants. Of note, is the fact that there was only one death in a TEMPSC that was not the result of drowning or hypothermia. That death (in the Vinland incident) was likely caused by a combination of severe stress factors: anxiety, fear of evacuating the rig, claustrophobia, etc. Seasickness, if it played a part, was likely a minor contributing factor. Without doubt, however, seasickness is a problem in TEMPSCs and Table 2 confirms this fact. The small size of a TEMPSC almost guarantees

.../35

TABLE 2

DRILLING RIG INCIDENTS

DRILLING RIG	DATE OF INCIDENCE	WEATHER CONDITIONS TIME OF INCIDENT	WEATHER CONDITIONS TIME OF RESCUE	COMPLEMENT OF PERSONNEL TOTAL	COMPLEMENT OF PERSONNEL IN TEMPSC	NUMBER OF DEATHS TOTAL	NUMBER OF DEATHS IN TEMPSC	CAUSE OF DEATH IN TEMPSC	TIME IN TEMPSC	INCIDENCE OF SEASICKNESS IN TEMPSC
Alexander L. Kielland	March 27/28, 1980	Winds: 39 knots Waves: 6-10 m	Somewhat improved	212	59	123	0	No deaths	Few hours	Almost 100%
Ocean Ranger	February 15, 1982	Winds: 75 knots Waves: 13-18 m	Similar during attempted rescue	84	30 or more	84	All	Drowning/ Hypothermia	1 hour*	Not known
Vinland	Feb 22/23, 1984	Winds: 25-30 knots Waves: 2.4-2.8 m	Less than 2 m	76	76	1	1**	Heart attack	8 hours	100%; 90% violently ill
Ocean Odyssey	Sept 22, 1988	Winds: 10-20 knots Waves: 1 m	Similar during rescue	67	58	1	0	No deaths	1/2 hour	75%***
Rowan Gorilla I	Dec 15, 1988	Winds: 50 knots Waves: 12-15 m	Winds: 30-35 knots Waves: 3.7-4.6 m	27	27	0	0	No deaths	22 hours	78%

* Refers to an estimated elapsed time between rig abandonment and unsuccessful rescue attempt by supply vessel, Seaforth Highlander. The TEMPSC was badly damaged, taking on water and capsized during the rescue attempt.

** To be technically correct, this victim was pronounced dead on arrival at the hospital.

*** Includes incidence of seasickness in 8 evacuees who jumped into the sea and were rescued by Zodiac® lifecraft, and those few personnel who became ill later, on board the standby vessel.

.../36

that most, if not all, occupants will become seasick shortly after launch, unless the sea is exceptionally calm. Even with waves as low as 1 m, the majority of survivors became seasick in the Ocean Odyssey evacuation.

The Rowan Gorilla I incident clearly demonstrates that survival-at-sea in an intact TEMPSC during severe sea and weather conditions is possible. Not only did the Whittaker survival capsule withstand the punishment of a raging sea, but its seasick occupants demonstrated the importance of adequate training and team work in survival. Training and leadership were also cited as contributing to the successful outcome of the Vinland incident.

As indicated elsewhere, whether or not seasickness was a factor in predisposing the Ocean Ranger riggers to hypothermia is not known. What is known is that the sole surviving TEMPSC with personnel aboard was damaged and taking on water; men were seen bailing water, while others were fit enough to scramble on to the gunwale. However, the men were exposed to extreme cold, and storm conditions were severe at the time, with no indication of immediate improvement. Given these conditions, it was necessary to attempt a rescue when the TEMPSC joined up with the Seaforth Highlander. This would not necessarily have been the case if the TEMPSC had remained intact and was self-righting. In that case, it would have been safest to leave the TEMPSC occupants alone, as in the case of the Rowan Gorilla I.

The reports from the Vinland, Ocean Odyssey and Rowan Gorilla I incidents are consistent in that the survivors have commented unfavourably on the habitability of the TEMPSC during sea survival conditions (for example, see the comments in Appendix I). Given that vomiting in seasickness is the main cause of loss of body fluids which can lead to death from dehydration and electrolytic imbalances, it would seem appropriate that the first stage in improving habitability in the TEMPSC would be to address that problem. The control of seasickness, providing something palatable to drink, the removal of offensive odours and heat, the implementation of good ventilation and correcting other problems are essential if occupants are to remain comfortable in their TEMPSC for many hours or even days until rescue conditions prevail. The addition of motion sickness bags at each seat location would alleviate the problem of having individuals vomit on each other.

Although it is beyond the scope of this study to consider the topic, the Alexander L. Kielland and Ocean Ranger disasters emphasize the need for developing sound techniques for launching TEMPSCs safely. In both disasters, the TEMPSCs were badly damaged while evacuating the semi-submersible units during severe winter storms. In that regard, the reports from the Royal Commission on the Ocean Ranger disaster discuss the problem in great depth (48,49). Notwithstanding the need for good launching techniques, there is also the need to improve the crashworthiness of the TEMPSC itself. Steps should be taken to investigate replacing the glass fibre-reinforced plastic protective shell with one employing impact-resistant composite materials in new TEMPSC designs. One of

.../37

the Rowan Gorilla I survivors had indicated that his greatest anxiety was the fear of not evacuating the rig successfully with the TEMPSC. Subsequent events were anticlimatic to that survivor.

Before the glass fibre TEMPSC was developed, survival in an open lifecraft was very difficult to achieve in heavy seas. It is now possible to survive virtually every storm if the TEMPSC is not damaged on launching. The development of the TEMPSC was a major step forward in survival equipment, without which it is quite possible that many of those on the Vinland and Rowan Gorilla I would have perished. So, survival is assured even though seasickness is quite a possibility.

.../38

CHAPTER 5.

CONTROLLING SEASICKNESS IN TEMPSC OCCUPANTS

There are principally 4 factors which contribute to make TEMPSC occupants highly susceptible to seasickness. The first is their sudden exposure to the unfamiliar and changing sea environment. The second is the fact that moderate-to-rough seas are not an uncommon occurrence in Eastern Canadian offshore waters. The third factor is the occupants' neurosensory mismatch resulting from the conflicting sensory stimuli and brain patterns of expectation. Fourth is the problem of the small size and nauseogenic environment of the TEMPSC itself. In all likelihood, most of its occupants will become seasick shortly after the lifeboat enters the water. Given this situation, what can be done to control the seasickness problem?

5.1. Sea Conditions in Eastern Canadian Coastal Waters

In order to address the problem of seasickness in TEMPSC occupants, it is necessary to understand the typical weather conditions affecting Eastern Canadian coastal waters. A report by Martec Limited (14) for COGLA provides much of this information. Of the different regions studied in the report, the severest sea storms occur in the Hibernia area of the Grand Banks off Newfoundland. Since this is the area in which most MODUs are currently conducting oil exploration, and in which the Ocean Ranger sank with subsequent loss of all lives, these data are used as a basis for assessing the problem of seasickness in rescue missions of TEMPSC occupants.

From December 1980 to mid-February 1982, Ocean Ranger experienced storms with an average duration $\pm$ standard deviation of 38.3 $\pm$ 19.7 hours. The average maximal combined wave height was 7.9 m (Sea State 6-7). If rig abandonment were to occur at the peak of such a storm, high winds above Sea State 5 (significant wave height = 3 m) would likely continue for a minimum of 24 to 36 hours. (The MARTEC report indicates that all rescue transfer at sea is difficult beyond Sea State 5.) Moreover, the median combined wave height for the years 1968 to 1979 for the Hibernia area was such that, from January to December, rescue transfer for Sea States greater than 5 would not be possible month by month for 52, 48, 41, 32, 20, 12, 10, 12, 22, 35, 41 and 48% of the time, respectively. Thus, in the Hibernia area, particularly during winter storms, rescue transfer at sea may not be possible for at least 36 hours, and, in some cases, for many days. The modern TEMPSC, if not damaged during rig abandonment, should be able to weather these sea conditions. Moreover, while the occupants may not be comfortable, given the will to live, they should all be able to survive. Therefore, it is necessary to look at the protective measures that can be implemented to ensure survival for 36 or more hours.

5.2. Singapore Navy Study of Seasickness Prevention

During the 1987 monsoon season in the South China Sea, How and

.../39

his colleagues (23) conducted a study which has relevance to the problem of seasickness protection for TEMPSC occupants. Observations of the extent of seasickness in naval personnel were made aboard a flat-bottomed vessel during double-blind trials for a period of 18 days at sea. The first 9 days were spent uninterrupted in open waters with Sea State conditions 1-4. The second 9 days, which were interrupted by two port calls of 4 days each, were spent mostly in coastal waters in Sea States 0-2. Participants in the trials were randomly placed into four groups: inexperienced personnel (less than a year in the Navy) using no seasickness medication but using a placebo patch; experienced personnel using the placebo patch; and both inexperienced and experienced personnel using commercially-available transdermal therapeutic patches containing 1.5 mg scopolamine (Scopderm TTS®). All patches were applied behind the ear 4 hours before sailing.

Figure 10 shows the mean seasickness scores (representing the severity of sickness in what How and his colleagues refer to as the "average" seaman) versus day of trip for seamen in both the placebo and drug-trial groups. Figure 11 shows the same type of information, but differentiates between the experienced and inexperienced groups.

In the placebo group, the degree of seasickness suffered by the "average" seaman was severe soon after going out to sea. Because of an individual's inherent ability to adapt to motion, the degree of seasickness lessened dramatically until about the 5th day of the trip; after that, it tended to correlate closely with the Sea State experienced for that day. Regardless of the severity of seasickness, the pattern of adaptation occurred at the same rate for all seamen. Inexperienced seamen initially suffered from more severe seasickness; however, after a few days, the difference in severity between inexperienced and experienced subjects was not statistically significant (Figure 11). In fact, experienced seamen were relatively immune to seasickness initially.

The degree of seasickness in the "average" seaman in the drug-trial group was statistically significantly lower than it was in the placebo group over the entire 18-day period (Figure 10). The difference was even more significant in the first 9 days. Scopolamine was most successful in reducing the severity of seasickness: (a) before adequate protective adaptation occurred (Figure 10); (b) amongst inexperienced seamen (Figure 11); and (c) at higher Sea States even after adaptation. Moreover, the protection rate; that is, the reduction in the incidence of seasickness, was 46-57% with the scopolamine patch.

The experimental conditions implicit in the Singapore Navy study are similar to those envisaged in oil rig abandonment in Eastern Canadian offshore waters: shallow-bottomed vessels (TEMPSCs), the possibility of several days at sea, the good chance of encountering moderate-to-rough seas, the inexperience of most TEMPSC occupants in sea travel, and the likelihood of seasickness in most of these occupants shortly after leaving the rig. It is obvious that a drug such as scopolamine is effective in reducing seasickness. The benefits of using

.../40

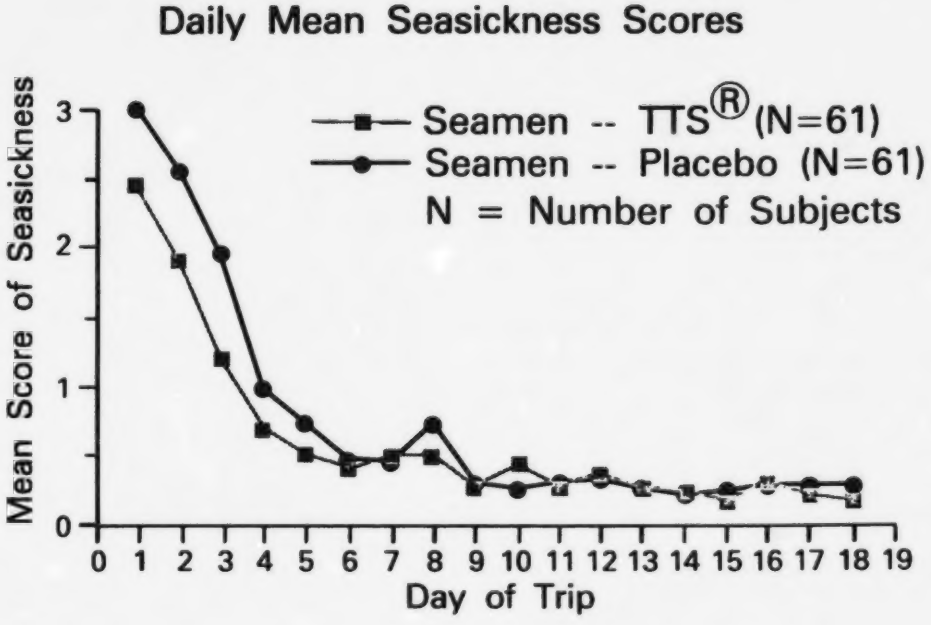
Daily Mean Seasickness Scores
Seamen -- TTS® (N=61)
Seamen -- Placebo (N=61)
N = Number of Subjects
Mean Score of Seasickness
0
1
2
3
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Day of Trip

FIGURE 10 Comparison of seasickness in "average" seamen using placebo patches (control group of 61 subjects) and transdermal scopolamine patches (61 subjects) for an 18-day trip at sea (from How et al., (23)).

.../41

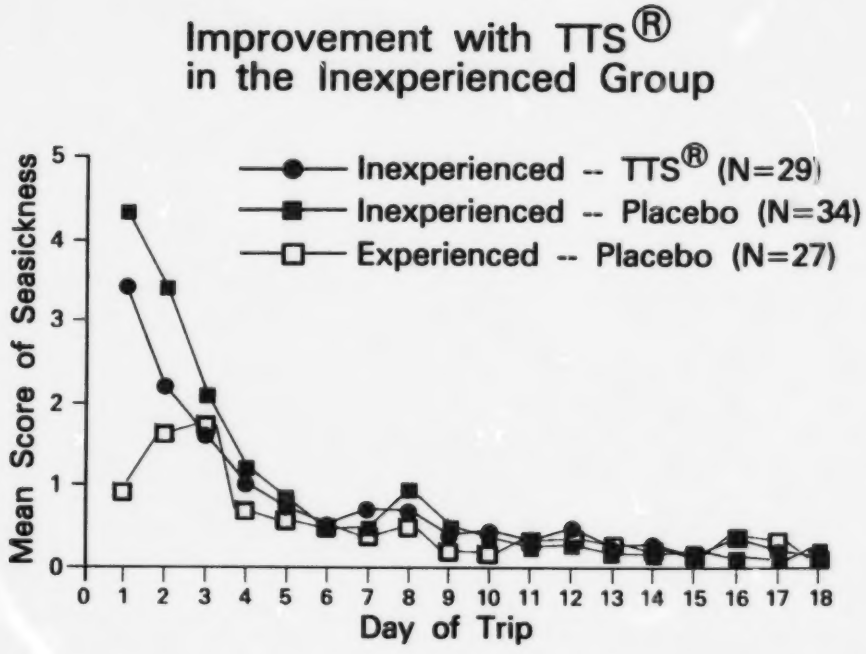

FIGURE 11 Comparison of seasickness in "average" seamen using placebo patches (34 inexperienced and 27 experiences subjects) and transdermal scopolamine patch (29 experienced personnel) (from How et al., (23)).

.../42

drugs, particularly fast-acting ones, in immediately reducing seasickness in TEMPSC occupants after they enter the sea is a desirable objective and should be explored further as a means of delaying the onset of dehydration.

5.3. Habitability of TEMPSC in Moderate-to-Rough Seas

Life aboard a TEMPSC under sea conditions that are prevalent in Eastern Canadian offshore waters is likely to be extremely uncomfortable for much of the year. Not only will occupants likely get seasick from bobbing up and down continuously for many hours, but they must contend with several other factors too. First, there is extreme terror and anxiety for survival itself, as the TEMPSC is jerked about in the water, possibly even being inverted at times. Craft vibration alone may be cause for alarm. The smell of vomit, feces, urine, diesel fumes and other odours is extremely nauseogenic, and is made worse by the seating arrangements -- occupants may be unable to direct their vomit except onto one another. Moreover, the small interior and the inability to see outside in such a vessel contributes to claustrophobia. The lack of windows was cited as a problem by 17% of the survivors of the Rowan Gorilla I (see Appendix I).

By regulation, TEMPSC occupants would normally wear closed-cell neoprene foam survival suits, and would be strapped into their seats by lap belts or shoulder harnesses. The inability to move about would be very tiring and stressful. Twenty-five percent of survivors in the Rowan Gorilla I incident indicated that overcrowding is a problem if design seating capacity is to be met; they recommended limiting the number of occupants allowed in a TEMPSC. TEMPSC occupants from the Vinland rig found their survival suits to be so "bulky" that they were not able to fasten their safety belts (59). With each individual contributing about 100 watts of heat energy continously inside the survival suit, the possibility of heat stress cannot be overlooked, particularly if oil rig abandonment occurs in the summer or during other warm air and water conditions. Profuse sweating inside the survival suit could seriously compound the dehydration associated with vomiting during seasickness. Twenty-eight percent of Rowan Gorilla survivors considered that excess heat within their TEMPSC contributed to their illnesses. As indicated elsewhere, the possibility of death due to rapid dehydration and loss of body electrolytes is a worrisome aspect of seasickness.

Although never reported, it is possible under lengthy survival conditions that anuria may occur; that is, the inability to produce urine as a result of severe dehydration produced by motion sickness. This could contribute to a buildup of toxic substances in the blood. Subsequent influences on health and well being could cause deleterious effects on body metabolism, especially amongst diabetics (54). Seventeen of twenty-four survivors of the Rowan Gorilla I incident did not urinate during the 22 hours that they were inside the TEMPSC. One evacuee was a diabetic.

.../43

The inherent poor ventilation of the TEMPSC itself will maintain a high internal temperature. Moreover, the poor ventilation may also cause a buildup of carbon dioxide, which could be life threatening to TEMPSC occupants who are forced by sea conditions to stay in the lifeboats for lengthy periods of time. This aspect needs further investigation. Although the diesel engines used to drive the TEMPSC should burn fuel efficiently if properly maintained, the possibility of generating a carbon monoxide buildup cannot be ignored and also needs to be addressed. If possible, improvements in fume reduction and control of ventilation should be retrofitted into current TEMPSCs. They should be mandatory in any new TEMPSC design. Four persons from the Rowan Gorilla I incident cited ventilation and the smell of diesel fumes as problem areas. The foul smell inside the TEMPSCs from the Vinland incident eventually caused the occupants to open the hatches during transit. The Research and Development Section of Robert Gordon's Institute of Technology Survival Centre, Aberdeen, United Kingdom is currently conducting a study on human survivability in the TEMPSC. Factors such as thermal stress, dehydration and carbon dioxide buildup are being assessed under realistic sea conditions (I. Light and M. Greenen, personal communication).

Because of the difficulty of ascribing the importance of the role of anxiety in motion sickness, the relationship between the two factors has been a contentious issue. However, the weight of evidence points to the motion stimulus characteristics as the primary causative factor of motion sickness; fear and anxiety are of secondary importance (4). Nevertheless, because of wide individual differences in susceptibility to motion sickness, it has been felt that personality differences may influence the way sensory information is processed. High levels of anxiety are known to decrease the capability of handling complex and/or demanding information processing. Therefore, anxiety may not only facilitate the induction of motion sickness, but may also hinder adaptation. A recent study by Fox and Arnon (15) showed that there may be a link between motion sickness and anxiety. This study, on male Israeli Flight Cadets, showed that the level of anxiety is significantly associated with the cadets' reports of their own motion sickness symptoms.

5.4. Drug Therapy

In TEMPSCs it is necessary to control the loss of body fluids by vomiting occupants in order to prevent rapid dehydration, and the loss of body electrolytes which can be life threatening if left unchecked. As the Singapore Navy study has shown, the best way of doing this is through the administration of antimotion sickness drugs.

There are many drugs available for controlling motion sickness (38); there are at least five that are considered to be highly efficacious in the prevention and treatment of motion sickness. These are scopolamine (hyoscine in the United Kingdom), promethazine, cyclizine, cinnarazine and dimenhydrinate. Amphetamine, used either alone or in combination with the others mentioned, is also effective;

.../44

but its use should be restricted because of its potential for abuse. Practical experience has shown that combinations of scopolamine and amphetamine are the most effective antimotion sickness medications, with ephedrine and promethazine combinations being slightly less effective (42). Amphetamine combined with scopolamine is a particularly effective combination because the amphetamine overcomes the side effects of the latter, and is the drug of choice of American astronauts in controlling Space sickness (50). Although cinnarizine has few side effects, and provides reasonably long-term protection, it is slow to achieve effective blood levels. A less effective drug, meclozine was used in the Vinland and Rowan Gorilla I incidents (see Chapter 4.). Table 3 lists these different drugs, the recommended doses, approximate times of onset of drug effect, approximate duration of effect, typical side effects and the conditions of motion for which they are most effective. The pharmacokinetics of oral and transdermal-patch scopolamine, and oral cinnarizine are compared in Figure 12.

The effectiveness of eleven different combinations of drugs in treating motion sickness was tested in double-blind trials at DCIEM (20). Subjects were rotated head-over-heels (about an axis through the ears) in darkness at 20 rpm. The different drug treatments, their efficacy rank order and rank score, and the number of side effects are shown in Table 4.

As indicated, treatments with the largest combination of drugs were not only the most effective, but also had the most side effects. Scopolamine alone, or scopolamine combined with another drug, had fewer side effects than combinations of promethazine and ephedrine. The TTS scopolamine patch by itself was an effective remedy. A statistical study of the efficacy of the various drugs showed no significant differences between any of them. (However, the placebo-alone and no-motion trials were significantly different from the drug treatments.) Other studies likewise fail to show firm conclusions regarding statistical differences in the efficacy of combinations of drug treatments (38).

It has been accepted that protection with drugs does not impair the natural ability to adapt to seasickness (4,45). However, a recent study shows that this may not be the case. Van Marion and his colleagues (58) have demonstrated that removal of the scopolamine patch after three days of seasickness protection resulted in significantly more vomiting in post-scopolamine subjects than in the post-placebo patched group.

5.4.1. Methods of Drug Administration

There are a number of routes by which antimotion sickness drugs can be administered: oral (tablet or inhalation), nasal (spray or drops), intramuscular injections, sublingual (tablet/sachet under the tongue), buccal (sachet/tablet in mouth cavity), rectal (suppository) and transdermal (patch). The method of drug administration should be chosen not only on the basis of how rapidly it can elevate blood serum

.../45

TABLE 3

DRUGS RECOMMENDED FOR MOTION SICKNESS

DRUG	DOSE (mg)	TIME OF ONSET (hours)	DURATION OF EFFECT (hours)	SIDE EFFECTS	SEVERITY OF MOTION
Amphetamine	5-10		8	Talkative, restlessness	Mild
Cinnarizine	30	2-5	6-8	Drowsiness	Mild to severe
Cyclizine	50	1-2	4-6	Slight drowsiness	Mild
Dimenhydrinate	50-100	1-2	6-8	Drowsiness, vertigo	Moderate
Meclozine	25-30	2	6-12	Drowsiness	
Promethazine	25	1.5-2	24-30	Extensive drowsiness	Moderate/ Severe
Promethazine/ Ephedrine	25/ 25	1-2	12		Moderate/ Severe
Scopolamine (Hyoscine)	0.3-0.6	0.5-1	4-6	Dry mouth, drowsiness, blurred vision	Severe
Scopolamine patch (TTS)	1.5	6-8	72	Dry mouth, drowsiness, blurred vision	Moderate/ Severe
Scopolamine/ Amphetamine	0.3-0.6/ 5-10	1-2	6	Slight dry mouth	Severe

NOTES: (1) Except for TTS patch, properties refer to oral routes of administration.

(2) Taken from References 4, 18, 38 and 45.

.../46

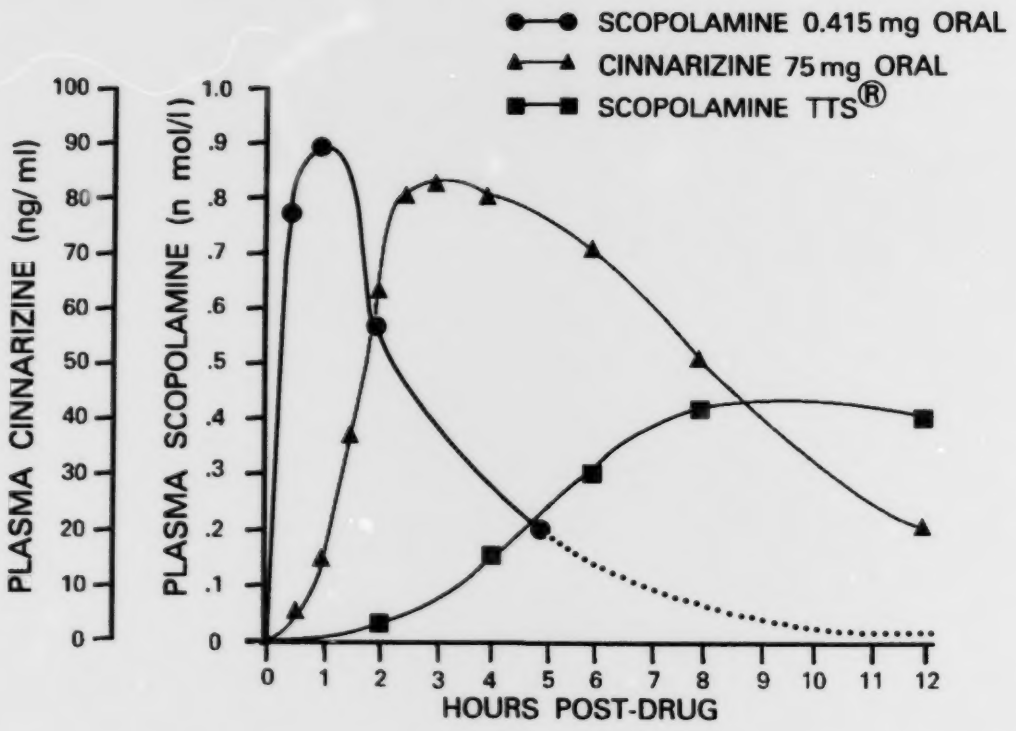

FIGURE 12 Comparisons of time courses of blood plasma levels (pharmacokinetics) of oral and transdermal-patch scopolamine, and oral cinnarizine following drug administration time equal to zero (from Golding et al., (19)). The duration of effect lasts approximately 12 hours for a 75 mg dose cinnarizine (18); other effects as in Table 3.

.../47

TABLE 4

COMPOSITION AND EFFECTIVENESS OF ELEVEN DRUG TREATMENTS

EFFICACY RANK ORDER	TTS TYPE	ORAL PREPARATIONS	EFFICACY RANK SCORE	NUMBER OF SIDE EFFECTS
1	Placebo	Placebo: no motion stimulus	1.44	7
2	Scopolamine	Scopolamine 0.25 mg + dexedrine (d-amphetamine) 5 mg + promethazine 25 mg + ephedrine 25 mg	3.55	39
3	Scopolamine	Promethazine 25 mg + ephedrine 25 mg	5.17	39
4	Placebo	Scopolamine 0.25 mg + dexedrine 5 mg + promethazine 25 mg + ephedrine 25 mg	5.27	28
5	Placebo	Promethazine 25 mg + ephedrine 25 mg	6.38	26
6	Scopolamine	Placebo (sodium bicarbonate)	6.55	17
7	Placebo	Scopolamine 0.25 mg + ephedrine 25 mg	6.61	18
8	Scopolamine	Scopolamine 0.25 mg + dexedrine 25 mg	6.78	26
9	Placebo	Scopolamine 0.25 mg + dexedrine 5 mg	7.00	18
10	Placebo	Scopolamine 0.25 mg	7.38	16
11	Placebo	Placebo	9.78	8

NOTES: (1) For efficacy, 1 is most effective and 11 is least effective.

(2) TTS patch applied 18 hours before trials; oral preparations taken 2 hours before.

(3) Taken from Gray et al. (20).

.../48

to therapeutic levels, but also on how fast it can cross the blood - brain barrier of the central nervous system (CNS), and be effective in suppressing symptoms of seasickness (18).

The oral, sublingual and buccal methods have the advantage that they are quick and simple. Tablets are easy to self-administer, simple to store, easily accessible and have a long shelf life. However, in a TEMPSC, vomiting is most likely to occur in most individuals in half an hour or less following rig abandonment, in which case the oral route is useless as most, if not all, of the drug would be lost resulting in unpredictable and, probably, subtherapeutic blood levels. Although sublingual and buccal sachets/tablets can be removed before vomiting under normal circumstances, this is hardly practical for TEMPSC occupants whose hands are covered by an integrated survival suit. Because of this factor, TEMPSC evacuees from the Ocean Odyssey MODU were not able to take their oral antimotion sickness medication until after they had removed their survival suits (Light and Greenen, personal communication). To be maximally effective in controlling seasickness at the critical time, the drug would have to be taken an hour or more before abandonment (except possibly for quick-acting forms of scopolamine -- see Table 3) using these routes. Many people also find tablets hard to swallow without liquid to assist swallowing, which can cause unnecessary anxiety, as happened to one of the survivors of Rowan Golilla I. Earlier work by Chinn and his co-workers (9) demonstrated that, although small scopolamine tablets placed under the tongue dissolved rapidly, they did not provide protection against air sickness. Studies are currently underway at the Institute of Naval Medicine, Gosport, United Kingdom to assess the efficacy of using cinnarizine in the buccal cavity. Nicholas Laboratories, Ltd. have also developed a quick-acting scopolamine sachet which can be "secured" inside the mouth (J.F. Golding, personal communication).

Rectal suppositories are also effective and easy to store. Benson (4) has recommended this method as an alternative to the intramuscular route for administering cyclizine in a survival situation. However, the average rigger may find the rectal method of administration both impractical and offensive, and would probably decide not to take anything. The drug would also have to be administered before donning the survival suit, which is not always possible, or, indeed, advisable in an emergency situation. Furthermore, once the survival suit has been zipped up and the TEMPSC occupants are restrained in their seats, any subsequent doses would be awkward and embarassing, if not impossible, to give. Cyclizine suppositories would require an hour or more lead time to be effective at the time of rig evacuation.

The intramuscular method can be very effective and quick acting. For example, pharmacokinetic studies show that scopolamine achieves a maximal blood serum level in 10 minutes following intramuscular injection (27,44). CNS induction times are not known (18); however, clinical effects appear to be delayed and long lasting in comparison to the rapid absorption and quick disappearance of the drug from the serum (28). The Royal Navy has used intramuscular doses of 0.2 mg scopolamine to prevent

.../49

seasickness in lifeboat occupants. Symptoms of seasickness were controlled in 86% of experimental subjects within 15 to 30 minutes of administration (6). Benson (4) recommends intramuscular injections of scopolamine, cyclizine or promethazine for controlling severe and repeated vomiting. Another study shows that severely sick subjects taking intramuscular injections of promethazine or scopolamine gained benefit within 10 minutes (21).

Intramuscular drug delivery has a number of deficiencies compared to routes that rely on tablets, patches or suppositories. The method requires reliance on a second person to administer the drug, unless a self-injection technique is used. Self-injection methods are considered efficient, but may be less than satisfactory for administering the drug to TEMPSC occupants wearing bulky survival suits. Then, too, the average rigger, even if trained to employ the self-injection device may be hesitant to use it if it means an injection. The unwarranted fear of puncturing a blood vessel may overcome the fear of seasickness; particularly, if the latter had never been experienced before. Appropriate instruction during survival training should overcome such fears. It might be possible to adapt the auto-injectors which are used to protect soldiers from chemical agents into self-injection devices for antimotion sickness drug injections. Appendix II describes some of the devices that are currently on the market (26). The possibility of self-administering an antimotion sickness drug directly into a muscle through the survival suit needs to be investigated. This method has been employed very effectively in applying antidotes to chemical agents through the charcoal-foam layer that makes up chemical defence garmetry. For instance, the Polyinject syringe manufactured by Poutrait-Morin, France could be suitable for use with neoprene survival suits (see Appendix II).

Nasal administration of antimotion sickness drugs is one method which could overcome some of the problems encountered with the other techniques. It is easily and (likely) willingly performed by the occupants themselves. The wearing of protective clothing should be no obstacle in drug delivery; nor should recurrent vomiting affect drug delivery to the blood stream. Furthermore, it eliminates the embarassment associated with suppositories. Two studies in the 1950's showed that scopolamine administered intranasally, either as a spray or in drops, provides protection against air sickness. Moreover, the speed of drug absorption was fast, occurring within 10 minutes (9,56). A further study to refine the technique, and assess its potential in preventing vomiting in seasickness is now needed. For example, nothing is known about the duration of effect for different drugs following nasal administration.

Drug administration directly into the lungs by means of oral inhalation from an aerosol container also has the potential for rapidly introducing the drug into the blood stream (27). Golding (18) expects a fast onset time for scopolamine aerosols or nasal sprays based on the analogy of the rapid absorption speed of other fast-acting drugs delivered by inhalation such as nicotine. This needs to be investigated further.

.../50

Drug delivery via transdermal patch has some advantages over other routes of administration. The drug is slowly absorbed direcly into the blood stream through the intact skin. Consequently, the drug avoids the powerful deactivation provided by the digestive processes and the direct first pass through the liver that occurs when taking tablets or suppositories. The patch is easily self-applied and delivers the drug over a prolonged period (51). Studies have shown that the transdermal scopolamine patch is effective in 75% of susceptible subjects, depending on the severity of motion (52). However, its disadvantage is that it must be applied 6 to 8 hours before motion commences (4,33,42). Moreover, in the conditions that might prevail just prior to rig evacuation, the neck may be oily and sweaty, and, therefore, render it impossible to apply the patch to the skin (18). Moreover, the oil may be a barrier to absorption. This requires further corroboration. Thus, transdermal administration is only recommended for long-term protection, and is not useful for immediate protection (2). Scopolamine is the only antimotion sickness drug that is being marketed in the form of a transdermal patch. Another disadvantage with the scopolamine patch is that there are inconsistencies in response both between individuals and between different patches on the same individual (42).

Regarding drug administration routes, Golding (18) confirmed that only oral ingestion, intramuscular injection and the transdermal patch are readily available at present. The impracticality of using suppositories rules them out as a possible method of administration in the TEMPSC.

5.5. The Management of Vomiting in Seasickness in TEMPSC Occupants

The good management of vomiting in seasickness is paramount if dehydration and body electrolytic imbalance are to be minimized and controlled. The first method for controlling vomiting in TEMPSC occupants depends on the choice of an effective drug regimen that combines the following features: easy administration, quick action, and long-term prophylaxis. Because of the small size of a TEMPSC (see Table 1) and the sea conditions envisaged, most of the occupants will become seasick. Even with drug therapy, a good proportion of TEMPSC occupants will probably suffer from seasickness and vomiting. Thus, it is imperative that an adequate supply of fluids, electrolytes and calories be maintained in the TEMPSC as a second line of defence against the excessive loss of body fluids if potential survival times of 36 hours or more are envisaged.

Scopolamine merits attention as the drug of choice because it is the most effective single drug for protecting against motion sickness. Its main disadvantage, like many other drugs or drug combinations, is that it affects the CNS (causing drowsiness) and the eyes (causing blurred vision, especially for near objects, making it difficult to read emergency checklists, etc.) (see Table 3). Both the degree of motion sickness protection and the severity of the side effects are dose-related; consequently, CNS functions such as attention and vigilance may have

.../51

to be compromised if adequate prophylaxis is to be provided (42). A high level of attention and vigilance is not required in the TEMPSC (except for the coxswain), only the will to survive. There is some evidence that the CNS side effects are reduced considerably during real or simulated ship motion compared to antimotion sickness drug trials conducted when there was no motion (2,13,23,42,55,58). In any case, the putative tranquilizing effects of scopolamine would probably be beneficial in counteracting some of the anxiety that TEMPSC occupants will likely encounter. If the Rowan Gorilla I incident is taken as an example, it may not be necessary to give the coxswain antimotion sickness medication as he/she may be the least likely individual to become seasick (see Figure I.1 in Appendix I). The coxswain is less susceptible because he can "drive" the TEMPSC and has the advantage of an external visual reference.

Since some TEMPSC occupants will become seasick and vomit within 15 minutes of entry into the water, there is a need to introduce scopolamine rapidly into the blood stream. A practical drug regimen for protecting against seasickness in TEMPSC occupants is recommended as follows: As soon as the need for rig abandonment has been established, the evacuees should take scopolamine by intramuscular injection for immediate prophylaxis. (The procedures for this implementation are beyond the scope of this document; that is, whether by self-administration, administration by a mate at the rig abandonment station, administration by rig medic, etc.) Currently, drug administration can be achieved rapidly enough only by an intramuscular injection of a 0.2 mg dose of scopolamine, which should be effective for some 4 to 6 hours (6,51). The profile of blood serum levels of scopolamine (as reflected in the urinary excretion rate) for a 0.2 mg dose is shown in Figure 13. CNS side effects for such a dose were not found severe in liferaft trials conducted by the Royal Navy (6). The drug should be administered directly through the survival suit into the vastus lateralis (outside mid-thigh muscle). Injection through the survival suit would not cause any significant leakage during any subsequent immersion. Alternatively, the drug could be introduced into the deltoid muscle, the prominent muscle covering the upper part of the arm. If an abandonment suit is worn at the time of drug delivery, the upper part of the suit can be unzippered and the drug administered.

Immediately after the intramuscular administration of scopolamine, a transdermal scopolamine patch should be secured behind the ear for long term prophylaxis. The patches take effect 6-8 hours after application, and, combined with the intramuscular injection, should assure that there will be continous pharmacological protection against seasickness for up to 72 hours (see Table 3). This two-stage method of drug administration should be sufficient for all practical purposes, and give protection for at least 36 hours (see Chapter 5).

(The times quoted in Table 3 are based on best estimates as compiled for a variety of motion conditions. However, it may be that, in TEMPSC occupants, the duration of effectiveness of the intramuscular scopolamine injection will be considerably less than the 4 to 6 hours

.../52

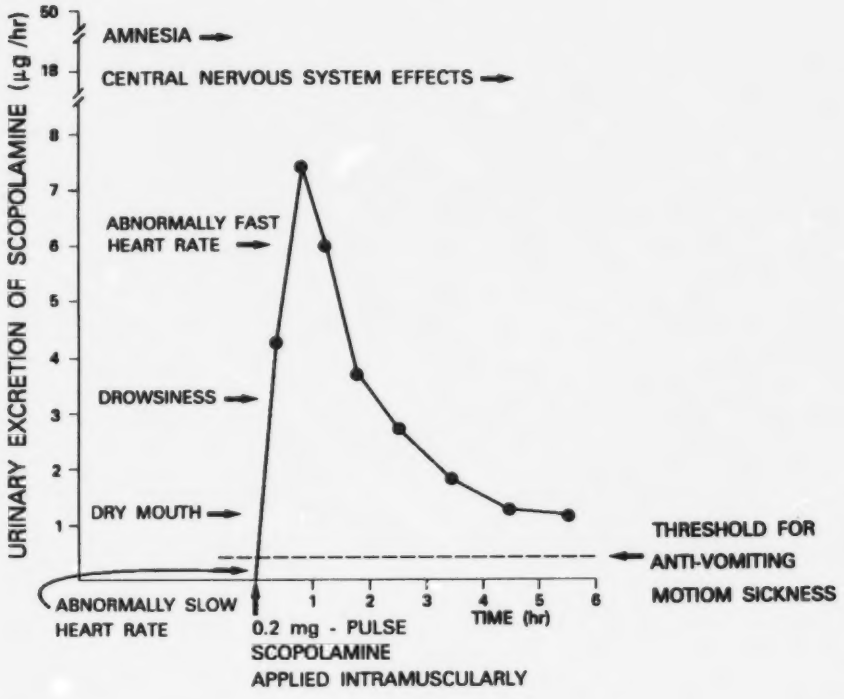

FIGURE 13 Blood serum level for a 0.2 mg injection dose of intramuscular scopolamine. Possible side effects and level for protection against vomiting are illustrated. Note that significant CNS side effects should not occur at this dosage with this method (from Shaw and Urquhart (51)).

.../53

quoted and/or the onset time of the scopolamine effects from the transdermal patch may be delayed beyond 8 hours. Should this happen, then a second intramuscular injection would be required in the TEMPSC. This may have to be investigated.)

Parrott (42) has written extensively on the possible side effects of transdermal scopolamine, while acknowledging its therapeutic properties. He emphasizes the fact that there may be differences between individuals both in the effectiveness of the drug and in the severity of the side effects. Thus, both intramuscular and transdermal scopolamine should be tested on each rigger during survival training in seasickness conditions in order to assess, for that individual, whether scopolamine is effective and if the side effects can be tolerated. If not, then intramuscular injections of promethazine or cyclizine should be tested on that individual as possible alternatives.

Kits containing adequate supplies of intramuscular scopolamine injections and transdermal patches should be kept at all rig sick bays, muster stations and at TEMPSC launching stations. Plastic bags containing potable water and electrolytes, palatable food and kits of intramuscular scopolamine and patches sufficient for stays up to 5 days in the lifeboat should be kept at each TEMPSC seat.

A special effort should be made to retrofit existing TEMPSCs with improved ventilation units. This will remove offensive odours which initiate and contribute to vomiting during seasickness, prevent the possibility of a buildup of carbon dioxide and/or carbon monoxide, and reduce the dehydrating effect of sweating that occurs during warm environmental conditions. An ample supply of motion sickness bags should be placed at each seat location. Heaters, to prevent possible hypothermia, should be installed for operation during winter months. The possibility of providing heat within the individual survival suit itself is also a viable longer term option. Chalk River Nuclear Laboratories, Chalk River, Ontario have developed a catalytic methanol heater for this purpose. DCIEM is supporting the development of the method for hand and foot warming in a diving suit. Whole body heating in survival suits is a potential application of this concept (T. Romet, personal communication). Additional unsatisfactory conditions aboard the TEMPSC have been identified by the survivors of Rowan Gorilla I. (These are listed in Item 30 in Appendix I.) Where practicable, they should be rectified.

.../54

CHAPTER 6.

CONCLUSIONS

Seasickness is the most common form of motion sickness. It can be explained by the neurosensory mismatch construct, whereby incongruent and discordant sensory information does not "match" with brain expectations from previous experiences. Seasickness is also a function of wave motion frequency and is prevalent at low frequencies in the range of 0.1 to 0.3 Hz. Adaptation to sea motion takes place over a period of 3 to 4 days.

Seasickness occurred in 75% or more of TEMPSC occupants in four of the five oil rig disasters that were analyzed in this report. (The extent of seasickness in the fifth rig disaster, the Ocean Ranger, is unknown.) It has occurred in relatively calm waters of wave height 1 m (Ocean Odyssey incident) and in severe seas of 15 m wave heights (Rowan Gorilla I).

A number of neurosensory mismatches and other provocative circumstances contribute to seasickness in TEMPSC occupants. These include:

a. the small confined space, with poor external visual reference;

b. the fact that occupants are passive passengers not in control of their own movements;

c. the seating arrangements that face in a variety of directions;

d. poor head support, which leads to excessive head movements;

e. the necessity to sit upright (rather than take a recumbent position which is known to reduce seasickness); and

f. the lack of a place to vomit, as well as the fact that the smell and sight of another vomiting are extremely potent nauseogenic stimuli.

These mismatches are important in explaining the seasickness resulting from the milder sea conditions such as those experienced by the Ocean Odyssey riggers. They are probably of less importance than the small size of the TEMPSC, and the associated claustrophobia and anxiety, in explaining the prevalence of seasickness in more severe conditions such as those encountered during the Rowan Gorilla I incident. In the latter case, seasickness is likely the result of an intravestibular neurosensory mismatch which associates TEMPSC movements with synchronized rotations rather than the true heave and pitch motion.

Because of its small size, nothing can be done to change the overall design of the TEMPSC so that its frequency and acceleration

.../55

magnitudes would be beyond those associated with motion sickness. Accordingly, for the near future, any methods for alleviating seasickness must consider improvements to the interior of the TEMPSC rather than the exterior. This includes providing good ventilation (for preventing the buildup of carbon dioxide and carbon monoxide, and removing odours from fumes and vomit), and temperature control.

Severe and repeated vomiting through seasickness can cause dehydration and the loss of body electrolytes, which could accelerate death if allowed to proceed for several days without implementing suitable remedial countermeasures. In oil rig disasters that occur during sea conditions of warm air and water, dehydration is accelerated by individual sweating in the TEMPSC (with or without the wearing of an abandonment suit).

Oil rig disasters that occur in cold weather conditions must guard against the possibility that seasickness in TEMPSC occupants may facilitate hypothermia if adequate heating is not supplied.

Dehydration and loss of body electrolytes or hypothermia, and motion sickness itself, if left unchecked, can cause a serious loss in morale and the will to survive concomitant with a total loss of interest or the inability to participate in survival or rescue attempts. This is the real danger that must be considered when discussing seasickness. Seasickness is most unlikely to cause death in TEMPSC occupants in any other way.

The authors have reviewed thousands of peacetime marine incidents as documented in Canadian Coast Guard reports, National Press clippings in the United Kingdom, literature reviews on the topic and records of oil rig abandonments. The one reported death in the Vinland abandonment appears to be the only one that could be even remotely associated with seasickness. Accordingly, it must be considered an aberration.

The Rowan Gorilla I incident has shown clearly the merits of leaving occupants in an intact TEMPSC alone until weather and sea conditions improve. The Martec Report suggests that those conditions commence at Sea State 5 (significant wave height = 3 m) or less. Rescue attempts above Sea State 5 should only be considered if there is immediate danger to the lives of the TEMPSC occupants. For example, even though unsuccessful, it was necessary to attempt such a rescue of the occupants in the severely-damaged TEMPSC from the Ocean Ranger.

The most effective way of controlling vomiting from seasickness is through the use of antimotion sickness drugs. Even though there are associated side effects, the current drug of choice would appear to be scopolamine, the most effective single drug for protecting against motion sickness. Seasickness prophylaxis by way of drugs should be instituted in two ways -- an intramuscular injection for immediate protection and the application of a transdermal scopolamine patch behind the ear for long-term protection.

.../56

Finally, all oil riggers should experience rough sea conditions that will cause seasickness during survival training. The importance of such training in maintaining their confidence was cited by more than one-third of the survivors of the Rowan Gorilla I incident. The riggers need to know that it is highly likely that they will become seasick in spite of the drugs (although less so if the stimulus is violent); that it is a natural response to which they can adapt; and having adapted, they will no longer be prone to seasickness. They also need to know that death from seasickness is extremely rare, and if it does occur, it should only come as a result of several days of dehydration, which can be controlled if proper precautions are taken.

.../57

CHAPTER 7.

RECOMMENDATIONS

The small size of a TEMPSC means that seasickness is inevitable, regardless of sea conditions. There is little evidence that seasickness contributes to death in the TEMPSC. Therefore, TEMPSC occupants should be left in their lifeboats until sea conditions are sufficiently moderate to effect a safe recovery, even if it takes several days. (If the lifeboat is damaged during rig evacuation to the extent that loss of lives through hypothermia and/or drowning is possible, then recovery of TEMPSC occupants should commence immediately, taking into regard the weather and sea conditions.) Given the fact that the ship's motion characteristics likely cannot be changed, this implies that little can be done to the overall design of the TEMPSC itself. Accordingly, efforts should be made to improve the habitability of the TEMPSC and the well-being of the evacuees with the view to reducing seasickness, dehydration, hypothermia, anxiety and the other factors that contribute to loss of comfort and the will to survive. These can be considered in terms of two phases: immediate solutions and long-term solutions.

Immediate solutions that should be considered are:

a. providing a good supply of motion sickness bags at each seat to reduce the incidence of evacuees vomiting on each other;

b. reducing the number of people on board each TEMPSC by 30 to 40% to reduce overcrowding;

c. filling the innermost TEMPSC seats first with occupants who are more susceptible to motion sickness;

d. retrofitting, where applicable, each TEMPSC seat with a four-point safety harness and padded back and head support to protect individuals during capsizing, and to restrain head and body movement at other times;

e. providing each TEMPSC with suitable environmental climate conditioning units to control heat in warm weather, cold in winter, and fresh air to remove carbon dioxide, carbon monoxide and bad odours;

f. retrofitting the coxswain's gauges with better dial illumination so that internal TEMPSC lighting need not be turned on, since this aggravates those evacuees who feel nauseated;

g. providing kits containing adequate antimotion sickness supplies of injectable intramuscular scopolamine (for fast action) and transdermal ear patches (for long-term protection) at each oil rig muster station, at TEMPSC launching stations and at each seat location within the TEMPSC. (The

.../58

exact procedures of how to implement such a recommendation is unfortunately beyond the scope of this paper.);

h. instructing each rigger appropriately on the necessity of administering both injectable and patch antimotion sickness medication as soon as the call for rig evacuation is made;

j. providing each rigger with training in hypodermic administration of intramuscular scopolamine;

k. having each rigger test their ability to tolerate scopolamine during survival training under medical supervision for conditions with and without ship motion (if not tolerated, they should repeat process with cyclizine or promethazine);

m. providing each rigger during survival training with the basic knowledge, technical skills and experiences for overcoming the fear of the sea, and how to handle problems of seasickness with special emphasis on leadership and the will to survive; and

n. providing sufficient plastic bags of potable water and necessary electrolytes, and palatable survival rations for each individual for stays up to 5 days in the TEMPSC.

Long-term solutions for consideration are:

a. improving crashworthiness by redesigning and fabricating the TEMPSC hull out of impact-resistant composite materials;

b. redesigning and fabricating the TEMPSC dome from impact-resistant transparent materials in order to provide visual reference in good sea conditions;

c. providing a retractable screen within the TEMPSC in order to shield against external visual cues in very bad sea conditions;

d. developing a totally integrated climatic control system for the automatic adjustment of the TEMPSC environment;

e. conducting further research into a drug of choice, which is specific for rig-abandonment evacuees, that optimizes efficacy, time of onset and duration of action, and has minimal side effects;

f. assessing the effectiveness and practicality of using nasal techniques, aerosols, buccal methods and self-injection devices over current methods of drug delivery; and, finally,

g. conducting a program of studies and making recommendations on how to reduce anxiety in TEMPSC occupants in a survival situation.

.../59

CHAPTER 8.

ACKNOWLEDGEMENTS

We are grateful to many people for their contributions to this study: to the survivors of Rowan Gorilla I for sharing with us their seasickness experiences, and Mr. R.M. Hattie, Rowan Companies, Inc., Halifax, for bringing them together for the interview; to Dr. I.M. Light, Capt. M.G. Greenen, Mr. I. Watson, Mr. A. Avery, Mr. J.H. Cross and others at Robert Gordon's Institute of Technology Offshore Survival Centre, Aberdeen, U.K., for providing information on the Ocean Odyssey incident, their motion sickness results from the evacuees, and for giving us the opportunity to participate in offshore survival training; to Dr. J.F. Golding, Surgeon Commander H. Oakley, Lt. C. Lloyd, CPO Muncaster and Mr. R. Strong, Institute of Naval Medicine, Gosport, U.K., for valuable information on anti-seasickness medication and methods of drug delivery, and giving us the opportunity to survey their file of National Press clippings for seasickness incidences; to Mr. A. Bohemier, Mr. D. Fox and others at Survival Systems International, Dartmouth, Nova Scotia, for the opportunity to take their survival training programme and providing valuable insight on the importance of experience at sea and leadership for TEMPSC-evacuee survival; to Capt. B. Thorne, Mr. S. Lavoie, Ms S. Hynes, and Mr. W. Vasilliou, Marine Casualty Investigations, Transport Canada, Ottawa, for making available to us marine accident reports for assessing seasickness incidences; to Dr. D. Offer-Ohlsen, Oslo, Norway, for providing extensive documentation on seasickness in the Alexander L. Kielland disaster; to P. Werenskiold, Norwegian Marine Technology Research Institute, Trondheim, and A. Pasche, T. Sten, O. Ingstad and T. Ulleberg of the Foundation for Scientific and Industrial REsearch at the Norwegian Institute of Technology, Trondhiem, and Dr. O.I. Molvaer, Norwegian Underwater Technology Centre, Bergen, and P. Brinchmann, Harding A/S, Rosendal, all of Norway for valuable tours and discussions pertaining to totally-enclosed lifeboats, ship motion, seasickness, cold water survival and environmental work stress; to Mr. L. Groeller for first-hand accounts of the Vinland incident, and Ms C. Macdonald for antimotion sickness policy, both from Shell Canada, Ltd., Calgary, Alberta; to Mr. J.A. Kelly, and Mr. J. Gow, Mobil Oil Canada Ltd., Calgary, and Mr. R. Kimberlin, Mobil Oil UK, London, for authorizing a visit to their oil rig "Beryl Bravo", and to Messrs. F. Huet, P. Woodhouse and D. Clarke, Beryl Bravo, Mobil North Sea Ltd., for discussions and tours of their facility; to Mr. J. Van Duinen, Bow Valley, Calgary, for arranging for a visit to their oil rig "Bow Drill I", and Mr. K. Valentine, Halifax, Nova Scotia, for a tour of that facility; to Mr. D.H. Robertson, Marine Technology Support Unit, Oxfordshire, and Mr. J. Austin, London, U.K., both with the Department of Energy for inviting us to attend their Rescue and Recovery Work-Group Meeting in London for discussions with oil industry representatives on TEMPSC occupant survival-at-sea; to Mr. J. Janson, National Board of Navigation, and Dr. L.A. Laitinen, Central Medical Hospital, both of Helsinki, Finland, for discussions on helicopter liferaft recovery and seasickness, respectively; to Messrs. T. Lander and J. Rankin, COGLA,

.../60

Halifax, for arranging facilities for interview with survivors of the Rowan Gorilla I; to Dr. J. Kanto, Turku University, Turku, Finland, for providing new information on pharmacokinetics of scopolamine; to Dr. H. Havig, the Norwegian Maritime Directorate, Oslo, for providing valuable information on several oil rig disasters; to Surgeon Commander B.J.W. Pingree, Royal Naval Sick Quarters, Helensburgh, U.K. for providing his informative treatise on seasickness; to Dr. W.H. Johnson, St. Michael's Hospital, Toronto for information on anuria in motion sickness; to Mr. P. Potter, The Cord Group Ltd., Halifax, for discussions on cold-water survival; to Messrs. A. MacDonald and D. Walsh, Halifax Nautical Institute, for discussions on lifeboat rescue and recovery; to Ms C. Fowler, DND Office of Information (Atlantic Region), Halifax, for providing photographs of a survival capsule; Mr. I.G. Wallace, CONOCO (UK), Aberdeen for helpful discussions on survival and seasickness in North Sea operations; and to Major G.C. Urquhart, Rescue Coordination Centre, Maritime Command Headquarters, Halifax, for meteorological and rescue information pertaining to the Rowan Gorilla incident.

Critical reviews of this report were provided by Dr. C.J. Brooks, Dr. K.E. Money and Dr. M.J. Ballantyne. June Parris, Edna Ashe, Maimo Fairbrother, and Brenda D. Zajakovski provided the typing; Mr. V. Praestegaard and Mr. E. Rypan the art work, Mr. B. Cheung the data reduction from the motion sickness questionnaire of the Rowan Gorilla I incident, and Mr. R.P.S. Cardin the editing of the report. We are very grateful for all these efforts.

Finally, we would like to acknowledge the guidance and advice of Dr. Shaun D. Gill, COGLA, Ottawa, who initiated and funded this project.

.../61

CHAPTER 9.

REFERENCES

1. ANDERSON, W.R., G.C. WILLEMS and J.C. GUIGNARD. Analysis of head motion during simulated, rough water operation of a 2200 ton surface effect ship. In: Motion Sickness: Mechanisms, Prediction, Prevention and Treatment. AGARD Conf. Proc No. 372, pp 38-1 to 38-14, 1984.

2. ATTIAS, J., C. GORDON, J. RIBAK, O. BINAH and A. ROLNICK. Efficacy of transdermal scopolamine against seasickness: A 3-day study at sea. Aviat. Space Environ. Med. 58: 60-62, 1987.

3. BARNES, G.R. Vestibular control of oculomotor and postural mechanisms. Clin. Phys. Physiol. Meas. 1:3-40, 1980.

4. BENSON, A.J. Motion Sickness. In: Aviation Medicine, 2nd Edition. Edited by J. Ernsting and P. King, Butterworths, London, 1988, pp.318-338.

5. BLES. W. Bewegingsziekte. Instituut voor Zintuigfysiologie TNO, Soesterberg, The Netherlands, Report #IZF 1983-21, 1983. (Translated by Secretary of State, Ottawa, Canada).

6. BRAND, J.J. and P. WHITTINGHAM. Intramuscular hyoscine in control of motion sickness. Lancet ii: 232-234, 1970.

7. BRYNE, H. and E. DAHL. Oil rig disaster in the North Sea. Presentation at 2nd World Congress on Emergency and Disaster Medicine, Pittsburgh, Pennsylvania, 31 May - 3 June, 1981.

8. Canadian Coast Guard Report of Investigation into the Circumstances Attending the Abandonment of the MODU "Vinland" on February 22, 1984 off Sable Island, Nova Scotia, Report #290, Canadian Coast Guard, Marine Casualty Investigations, Ottawa.

9. CHINN, H.I., R.W. HYDE and L.J. MILCH. Prevention and treatment of motion sickness by intranasal medication. Proc. Soc. Expr. Biol. Med. 90: 666-669, 1955.

10. CHINN, H.I. Motion sickness in military service. Mil Surgeon. 108: 20-29, 1951.

11. CLAREMONT, C.A. The psychology of seasickness. Psyche 11: 86-90, 1931.

12. Coast Guard Study into Fishing Vessel Safety. Coast Guard Working Group on Fishing Vessel Safety, 19 October 1987.

.../62

13. DAHL, E., D. OFFER-OHLSEN, P.E. LILLEVOLD and L. SANDVIK. Transdermal scopolamine, oral meclizine and placebo in motion sickness. Clin. Pharmacol. Ther. 36: 116-120, 1984.

14. Evaluation of Emergency Equipment and Sea Rescue Techniques for Use from Mobile Offshore Drilling Units in Canadian Waters. Draft Report to COGLA from Martec Limited, 5670 Spring Garden Road, Halifax, N.S. March 1983.

15. FOX, S. and I. ARNON. Motion sickness and anxiety. Aviat. Space Environ. Med. 59: 728-733, 1988.

16. FRANK, L.H., R.S. KENNEDY, M.E. MCCAULEY and R.S. KELLOGG. Simulator Sickness: Reaction to a Transformed Perceptual World. I. Scope of the Problem. Report NAVTRAEQUIPCEN TN-65. Naval Training Equipment Centre, Orlando, Florida. 1983.

17. GILLINGHAM, K.K. and J.W. WOLFE. Spatial orientation in flight. In: Fundamentals of Aerospace Medicine. Edited by R.L. DeHart, Lea & Febinger, Philadelphia, 1985, pp.299-381.

18. GOLDING, J.F. Motion Sickness in the Submarine Escape Immersion Suit (SEIS). An Assessment and Proposals. Human Factors Division, R.N. Institute of Naval Medicine, Gosport, United Kingdom, September, 1988.

19. GOLDING, J.F., R. STRONG and R. PETHYBRIDGE. Time-Course of Oral Cinnarizine Effects on Task Performance. R.N. Institute of Naval Medicine, Gosport, U.K. INM Report 18/88, 1988.

20. GRAY, S., B. CHEUNG, K. MONEY, J. LANDOLT and R. CRAGG. Effectiveness of combinations of antimotion sickness drugs. In: Preprints to Aerospace Medical Association Meeting, Houston, Texas, 23-26 May 1983, pp.61-62, 1983.

21. GRAYBIEL, A. and J.R. LACKNER. Treatment of severe motion sickness with antimotion sickness drug injections. Aviat. Space Environ. Med. 58: 773-776, 1987.

22. HARDY, M. Observations on the innervation of the macula sacculi in man. Anat. Rec. 59: 403-418, 1934.

23. HOW, J., P.-S. LEE, L.-C. SEET and P.-K. TAN. The Republic of Singapore Navy's Scopderm TTS study: Results after 2,200 man-days at sea. Aviat. Space Environ. Med. 59: 646-650, 1988.

24. HOWARD, I.P. The perception of posture, self-motion and the visual vertical. In: Handbook of Perception and Human Performance, Volume I, Sensory Processes and Perception. Edited by K.R. Boff, L. Kaufman and J.P. Thomas, John Wiley & Sons, New York, 1986, pp.18-1 - 18-62.

.../63

25. International Standardization Organization, ISO 2631/3 - 1985. Evaluation of Human Exposure to Whole-Body Vibration. Part 3: Evaluation of Exposure to Whole-Body Z - Axis Vertical Vibration in the Frequency Range 0.1 to 0.63 Hz, 1985, pp.1-4.

26. Jane's NBC Protection Equipment, 1988-89, 1st Edition. Edited by T.J. Gander, Jane's Information Group, Surrey, United Kingdom, pp.142-144.

27. KANTO, J. and U. KLOTZ. Pharmacokinetic implications for the clinical use of atropine, scopolamine and glycopyrrolate. Acta Anaesthesiol. Scand. 32: 69-78, 1988.

28. KANTO, J., E. KENTALA, T. KAILA and K. PIHLAJAMAKI. Pharmacokinetics of scopolamine during caesarian section: Relationship between serum concentration and effect. Acta Anaesthesiol. Scand. 1989 (in press).

29. LAWTHER, A. and M.J. GRIFFIN. The motion of a ship at sea and the consequent motion sickness amongst passengers. Ergonomics 29: 535-552, 1986.

30. LAWTHER, A. and M.J. GRIFFIN. Prediction of the incidence of motion sickness from the magnitude, frequency, and duration of vertical oscillation. J. Acoust. Soc. Am. 82: 957-966, 1987.

31. LAWTHER, A. and M.J. GRIFFIN. A survey of the occurrence of motion sickness amongst passengers at sea. Aviat. Space Environ. Med. 59: 399-406, 1988.

32. LAWTHER, A. and M.J. GRIFFIN. Motion sickness and motion characteristics of vessels at sea. Ergonomics 31: 1373-1394, 1988.

33. LEVY, G.D. and M.H. RAPAPORT. Transderm scopolamine efficacy related to time of application prior to the onset of motion. Aviat. Space Environ. Med. 56: 591-593, 1985.

34. LOW, A. Seekrankheit. In: Internistische Pharmakotherapie. Richtlinien und Empfehlungen fuer Praxis und Klinik, Munich, FRG, 1985, pp.1262-1265. (Translated by Naval Intelligence Support Center, Washington, D.C., NISC Translation #8324, 1987).

35. MCCAULEY, M.E., J.W. ROYAL, C.D. WYLIE, J.F. O'HANLON and R.R. MACKIE. Motion Sickness Incidence: Exploratory Studies of Habituation, Pitch and Roll, and the Refinement of a Mathematical Model. Human Factors Research Inc., Goleta, California, Technical Report 1733-2, 1976.

36. MONEY, K.E. Motion sickness. Physiol. Rev. 50: 1-39, 1970.

.../64

37. MONEY, K.E. and B.S. CHEUNG. Another function of the inner ear: Facilitation of the emetic response to poisons. Aviat. Space Environ. Med. 54: 208-211, 1983.

38. MUIR, C.A. Motion Illness -- A Bibliography. Medical Research Council, London, Report #SMWP-1/83, pp.1-115, 1983.

39. Norwegian Public Reports, The "Alexander L. Keilland" Accident. Prepared by Royal Norwegian Enquiry Commission, NOU 1981:11.

40. OFFER-OHLSEN, D. Hypothermia and evacuation problems in connection with the disaster concerning the accommodation platform "Alexander L. Kielland" March 1980. In: Hypothermia with Distress at Sea. Edited by U. Klein, M. Kohfahl and P. Kock, Cuxhaven, West Germany, 22-24 April 1982, pp.175-177.

41. O'HANLON, J.F. and M.E. MCCAULEY. Motion sickness incidence as a function of the frequency and acceleration of vertical sinusoidal motion. Aerospace Med. 45: 366-369, 1974.

42. PARROTT, A.C. Transdermal scopolamine: A review of its effects upon motion sickness, psychological performance, and physiological functioning. Aviat. Space Environ. Med. 60: 1-9, 1989.

43. PETHYBRIDGE, R.J. Sea Sickness Incidence in RN Ships. RN Institute of Naval Medicine, Gosport, U.K. INM Report 37/82, 1982.

44. PIHLAJAMAKI, K.K., J.H. KANTO and K.-M. OKSMAN-CALDENTEY. Pharmacokinetics and clinical effects of scopolamine in caesarian section patients. Acta pharmacol. et toxicol. 59: 259-262, 1986.

45. PINGREE, B.J.W. Emotion commotion -- A seasickness update. J. roy. nav. med. Serv. (in press) 1989.

46. REASON, J.T. and J.J. BRAND. Motion Sickness, Academic Press, London, 1975.

47. Report of Investigation of Events Culminating in a Blowout of Gas and Condensate at Shell Et Al Uniacke G-72. Prepared by the Board of Investigation, Halifax, Nova Scotia, June 5, 1984 for Canada Oil and Gas Lands Administration.

48. Report One: The Loss of the Semisubmersible Drill Rig Ocean Ranger and its Crew, Royal Commission on the Ocean Ranger Marine Disaster, Supply and Services Canada, Ottawa, Canada, 1984.

49. Report Two: Safety Offshore Eastern Canada, Royal Commission, The Ocean Ranger Marine Disaster, Supply and Services Canada, Ottawa, Canada, 1986.

.../65

50. SCHMEDTJE JR., J.F., C.M. OMAN, R. LETZ and E.L. BAKER. Effects of scopolamine and dextroamphetamine on human performance. Aviat. Space Environ. Med. 59: 407-410, 1988.

51. SHAW, J. and J. URQUHART. Programmed, systemic drug delivery by the transdermal route. TIPS 1: 208-211, 1979-80.

52. SHAW, J. and J. URQUHART. Transdermal drug administration - A nuisance becomes an opportunity. Br. Med. J. 283: 875-876, 1981.

53. SMITH, F.E. Survival at Sea. Medical Research Council, London. Report No. RNPRC - S1U/76, pp.1-124, 1976.

54. TAYLOR, N.B.G., J. HUNTER and W.H. JOHNSON. Antidiuresis as a measurement of induced motion sickness. Can. J. Biochem. Physiol. 35: 1017-1017, 1957.

55. TOKOLA, O., L.A. LAITINEN, J. AHO, G. GOTHONI and H. VAPAATALO. Drug treatment of motion sickness: Scopolamine alone and combined with ephedrine in real and simulated situations. Aviat. Space Environ. Med. 55: 636-641, 1984.

56. TONNDORF, J., R.W. HYDE, H.I. CHINN and J.E. LETT. Absorption from nasal mucous membrane: Systemic effect of hyoscine following intranasal administration. Ann. Otol. Rhin. Laryng. 62: 630-641, 1953.

57. TREISMAN, M. Motion sickness: An evolutionary hypothesis. Science 197: 493-495, 1977.

58. VAN MARION, W.F., M.C.M. BONGAERTS, J.C. CHRISTIAANSE, H.G. HOFKAMP and W. VAN OUWERKERK. Influence of transdermal scopolamine on motion sickness during 7 days' exposure to heavy seas. Clin. Pharmacol. Ther. 38: 301-305, 1985.

59. Vinland Gas Blow-Out and Evacuation, English Translation of Norwegian Report, 22 February 1984, Norwegian Maritime Directory, Oslo, 1984.

60. WAESPE, W. and U. HENN. Neuronal activity in the vestibular nuclei of the alert monkey during vestibular and optokinetic stimulation. Exp. Brain Res. 27: 523-538, 1977.

ROWAN GORILLA I

MOTION SICKNESS QUESTIONNAIRE: SUMMARY OF RESULTS

Composite results of a survey on the effects of sea time in the TEMPSC (survival capsule) from 24 of 27 occupants.

	RESPONSES NO.	PERCENTAGE
1. Do you travel regularly on ships?		
Rarely or never before	5	20.8
Twice a year or less	5	20.8
Up to 6 times a year	8	33.3
More than 6 times a year	6	25.0
2. Which one of the following statements corresponds most closely with the worst you have ever felt during your stay in the TEMPSC:		
I felt all right	3	12.5
I felt slightly unwell	12	50.0
I felt quite ill	4	16.7
I felt absolutely dreadful	5	20.8
3. If you did feel unwell, how soon after leaving the platform did this start?		
Half an hour or less	15	62.5
1 hour	3	12.5
2 hours	2	8.3
3 hours or more	1	4.2
No response	3	12.5
4. Did you feel unwell:		
In the survival capsule?		
Yes	20	83.3
No	4	16.7
At time of rescue?		
Yes	7	29.2
No	15	62.5
No response	2	8.3
Onboard rescue tugboat?		
Yes	1	4.2
No	21	87.5
No response	2	8.3

.../2

	RESPONSES NO.	PERCENTAGE
5. Did you vomit? If so, how soon after leaving the platform?		
No	6	25.0
Half an hour or less	12	50.0
1 hour	3	12.5
2 hours	2	8.3
3 hours or more	1	4.2
6. If you did get seasick, did you feel that you were becoming less sick as time went on, that is, were you adapting to the sea motion?		
Yes	16	66.7
No	7	29.2
No response	1	4.2
7. Are you prone to seasickness:		
Yes	6	25.0
No	17	70.8
Only in small craft	1	4.2
8. Which of the following, if any, caused your sickness?		
Heat	9	37.5
Cold	0	0
Cigarette smoke	0	0
Diesel fumes	4	16.7
Vibration	0	0
Lack of Windows to see out	4	16.7
Darkness of night	0	0
Small size of survival capsule	7	29.2
Seating arrangement	3	12.5
Smell of urine	0	0
Smell of feces	1	4.2
Someone else vomiting	14	58.3
Lack of head support	1	4.2
Apprehension	2	8.3
Inactivity	1	4.2
9. Please list any others not in our list.		
Daylight	2	8.3
Lack of ventilation	1	4.2
Light on in cabin	2	8.3

.../3

	RESPONSES NO.	PERCENTAGE
10. Given the choice, would you have preferred lying down to sitting upright in the TEMPSC?		
Yes	15	62.5
No	4	16.7
Maybe	2	8.3
No response	3	4.2
11. Did you urinate in the TEMPSC? If so, how often?		
No	17	70.8
Once	4	16.7
Twice	2	8.3
More than twice	1	4.2
12. Had you taken any anti-seasickness drugs?		
Yes	23	95.8
No	1	4.2
Please indicate form:		
Tablet	18	75.0
Transdermal patch	1	4.2
Tablet and suppository	1	4.2
Tablet and transdermal patch	3	12.5
None	1	4.2
13. If you did take anti-seasickness drugs, how many did you take?		
One	8	33.3
Two	9	37.5
More than two	6	25.0
None	1	4.2
14. Did you have any alcoholic drinks in the 24 hours before abandoning the rig?		
Yes	0	0
No	24	100
15. Did you have any spicy food, that is, chili, curry, etc. in the 24 hours before abandoning the rig?		
Yes	0	0
No	24	100

.../4

	RESPONSES NO.	PERCENTAGE
16. Age: Please tick the appropriate box:		
Under 18	0	0
18 - 39	17	70.8
40 - 60	7	29.2
Over 60	0	0
17. Sex: Please tick the appropriate box:		
Male	22	91.7
Female	2	8.3
18. What clothing did you wear?		
Sweat shirt, coveralls, or underwear	23	95.8
No response	1	4.2
19. Was a survival suit worn?		
Yes	23	95.8
No	1	4.2
20. Was suit removed inside TEMPSC?		
Yes	2	8.3
Partially removed (to waist)	16	66.7
No	6	25.0
21. What was it like inside the TEMPSC?		
Hot	20	83.3
Stuffy	20	83.3
Smelly	11	45.8
Fumey	5	20.8
Sweaty	15	62.5
Comfortable	2	8.3
Insufficient space	1	4.2
Uncomfortable	1	4.2
22. Did you feel the TEMPSC engine running?		
Yes	22	91.7
No	1	4.2
No response	1	4.2
23. Did you take any medication in addition to anti-seasickness drugs?		
Yes	1	4.2
No	23	95.8

.../5

	RESPONSES NO.	PERCENTAGE
24. What state were you in at time of rescue from the TEMPSC?		
Not injured	17	70.8
Seasick	7	29.2
Vomiting	2	8.3
Sweating	10	47.6
Dehydrated	10	47.6
Hot	1	4.2
Good motor ability		
Yes	20	83.3
No	1	4.2
No response	3	12.5
Good physical strength		
Yes	22	91.7
No	2	8.3
Good mental attitude		
Yes	23	95.8
No	1	4.2

25. If you were injured, how did this happen?

Injured knees when boarding the boat.

26. Please indicate where you sat in the attached diagram of seating positions in the TEMPSC.

See Figure I.1

27. How much survival training have you taken on what seasickness is all about, and what you should do about it?

None	0	0
A little	13	54.2
Quite a bit	11	45.8

.../6

	RESPONSES NO.	PERCENTAGE
28. Based on your experience in the Rowan Gorilla I incident, please indicate what else, if anything, should be taught during survival training as it relates to seasickness.		
Limit movement (stay strapped in).....	1	4.2
Limit drinking water initially.....	2	8.3
Keep positive attitude.....	1	4.2
Leave lights off.....	1	4.2
Need for early administration of anti-seasickness drug.....	1	4.2
Nothing else.....	7	29.2
No response.....	9	37.5
29. Please indicate what you consider to be the most important factor that contributed to your survival?		
Cooperative and obedient crew.....	9	37.5
Did not panic.....	6	25.0
Training.....	12	50.0
Positive attitude.....	2	8.3
Survival capsule.....	4	16.7
When rescued.....	1	4.2
No response.....	1	4.2
30. Please add any other information that you feel may be of importance to this study.		
Better seats (seat belt assembly, back support, padding).....	5	20.8
Limit number of persons in the TEMPSC.....	6	25.0
Improved ventilation.....		
Running lights mounted on the outside of capsule.....	8	33.3
Better radio (rechargeable battery).....	3	12.5
Better radar reflector.....	2	8.3
Illuminate gauges on dashboard.....	1	4.2
Reposition compass for better viewing.....	1	4.2
Better method of distributing potable water..	2	8.3
Establish abandonment procedures before entering capsule.....	1	4.2
Larger capsule.....	1	4.2
More comfortable capsule.....	1	4.2
More vomit buckets and paper towels.....	1	4.2
Water in plastic bag instead of can.....	1	4.2
Candy to suck on.....	1	4.2
Better food supply.....	1	4.2
No response.....	6	25.0

.../7

31. Specific Comments

(1) One survivor was not able to smell for 5 days after abandoning the rig.

(2) Many survivors felt that it is too crowded in the 34/38-man Whittaker survival capsule for 27 people fully clothed with abandonment suits.

(3) One survivor commented that the rougher the sea, the better he felt. In calmer "choppy" seas, the capsule seemed to rock more.

(4) One survivor vomited 2 minutes after reaching the sea during rig abandonment.

(5) Some survivors commented that they felt better during darkness; however, as soon as the coxswain turned on his lights to see the gauges, they became sick.

NOTE: In Items 8, 9, 21, 28, 29 and 30 more than one response was given by each person.

.../8

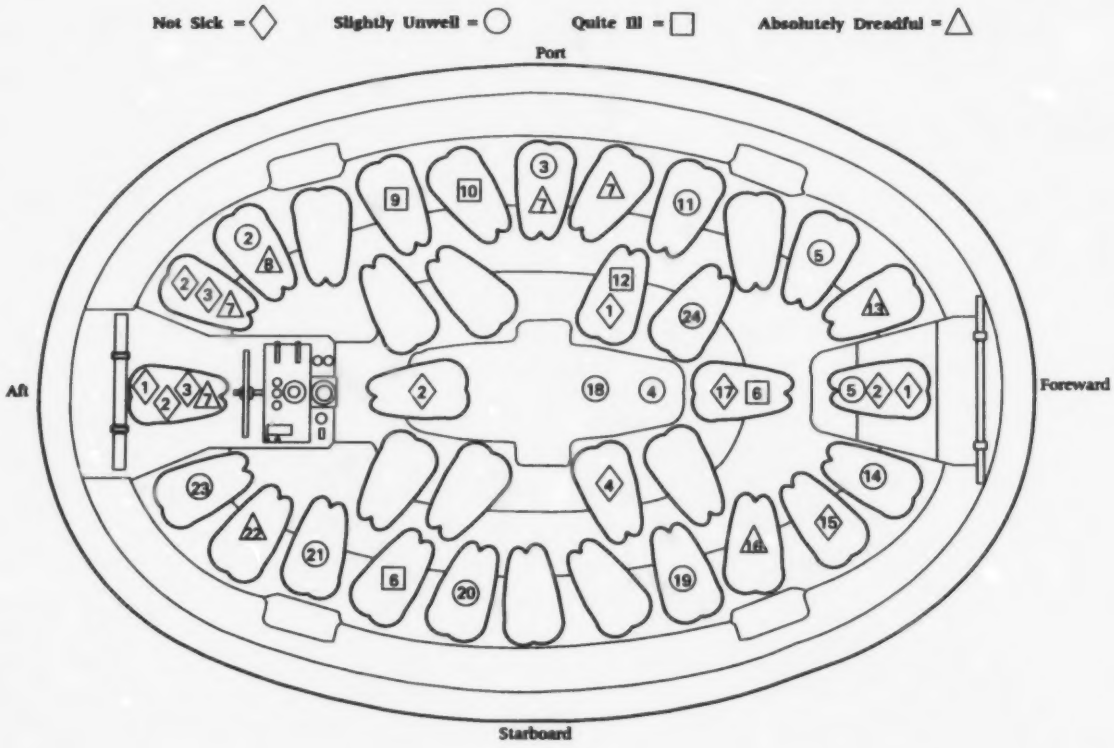

FIGURE I.1 Seating position in the 34/38 Whittaker TEMPSC for 24 of 27 survivors. Some riggers, who occupied more than one position during their 22-hour ordeal, felt differently at different seat positions. For example, rigger #2 felt slightly unwell at one position, but was not sick at the others. In some locations, where more than one rigger shared the same seat, it likely means that one of them occupied an adjacent seat. Riggers #4 and #18 occupied non-designated seat positions.

AUTO-INJECTORS FOR SELF-ADMINISTRATION OF CHEMICAL OR NERVE AGENTS

Two countries, France and The Netherlands, manufacture auto-injectors for self-administering anti-poison antidotes. The following descriptions are taken verbatim from Jane's NBC Protection Equipment (26).

1. Polyinject Syringe

a. Description

Poutrait-Morin produced their first auto-inject syringe for the French Armed Forces in 1967. The latest version is the Polyinject, produced in association with Walbam Medical Services, which can contain up to three different nerve agent or other chemical agent antidotes for self-administration in one operation.

The Polyinject is a multi-chambered, pressure activated self-injector syringe with the antidote solutions contained within the main body of the syringe. The chambers are separated by a system of rubber valves with the volume and number of compartments variable according to the antidote solutions and their volume. The maximum volume for two solutions is 5.5 millilitres. Each additional compartment or chamber decreases the total capacity by 1 millilitre. A double bevelled needle is fitted with an external diameter of 0.9 mm and an internal diameter of 0.6 mm. The exposed length of the needle after injection is 20 mm and it is capable of penetrating several layers of protective or other clothing.

Each Polyinject is issued sealed in an individual blister pack with each syringe bearing a simple illustrated instruction label. After unwrapping, a safety cap is removed and the Polyinject is placed against the thigh muscles. A button on the end of the syringe is then pressed and the automatic injection of the various antidote solutions is made without the solutions mixing in the syringe. The entire operation takes between 4 to 6 seconds.

The Polyinject weights 48 grams and is 152 mm long; the diameter is 21 mm.

Status

In production. In service with the French Armed Forces.

Manufacturer

Poutrait-Morin, 25 rue de la Courneuve, 93300, Aubervilliers, France.

.../2

2. AtroPen, ComboPen and MultiPen Nerve Agent Antidotes

a. Description

The terms AtroPen, ComboPen and MultiPen are registered trade names for auto-injectors. They are hypodermic devices meant for self-administration and are issued to personnel likely to encounter nerve agents.

The AtroPen contains atropine only and counters the symptoms of nerve agent poisoning. The device is 90 mm long and 12 mm in diameter.

The ComboPen contains a solution of water soluble medicaments (atropine and oxime). The device is 145 mm long and 20 mm in diameter. (The ComboPen is in service with the British Armed Forces as the Autoject (ComboPen) Nerve Agent Antidote L2A1. The L3A1 is a training device.)

The MultiPen may contain up to three medicaments stored separately and, for example, makes it possible to combine the water-insoluble diazepam with other nerve agent antidotes. The device is 170 mm and 22 mm in diameter.

All three devices are used in the same manner. The safety cap is removed from the end and the injector is pressed against the outer thigh muscles. Further pressure on a button releases a needle which can penetrate combat clothing and the body skin to introduce the atropine-based nerve agent antidote in the body. The needle is held in place for five seconds and the device then can be discarded. If nerve agent symptoms persist the self-treatment is repeated after 15 minutes. Instruction for use are printed on the body of the device.

If required the device can be fitted with a tablet holder to contain an anti-convulsant tablet such as 5 mg diazepam (Valium).

For training, an inert version with no needle or medical content is available. In place of the needle a blunt plastic button is projected and the device can be re-cocked with a special capattachment.

Various types of filling other than the nerve agent antidote can be used, and if required the ComboPen can be reloaded using a cartridge that contains the agent and a needle.

In June 1987 Duphar were awarded a contract worth $4,508,905. to supply 1,610,323 atropine injection kits to the American Defence Logistics Agency by July 1988.

.../3

Status

AtroPen and ComboPen: In production and in service with several NATO nations including the United Kingdom and the United States
MultiPen: Pre-production.

Manufacturer

Duphar BV. Medical Devices Division, Drentestraat 11, 1083 HK Amsterdam, Netherlands.

INDEX OF FACT-FINDING VISITS

1. Ottawa, Ontario

   a. Meeting: Dr. S.D. Gill, COGLA -- Project briefing and receipt of Ocean Ranger report and TEMPSC information;

   b. Meeting: Capt. B. Thorne, Transport Canada, Marine Casualty Investigations -- Review of marine incidents involving lifeboats and liferafts;

   c. National Archives -- Marine incident review;

   d. Meeting: Dr. K.E. Money, Canadian Astronaut Program, National Research Council of Canada -- Discussion of motion sickness; and

   e. Conference: Nausea and Vomiting, November 1988 -- Discussions with Surgeon Commander B.J.W. Pingree, Royal Navy and Dr. J.F. Golding, Institute of Naval Medicine, Gosport, U.K., on seasickness.

2. Halifax/Dartmouth, Nova Scotia

   a. Meeting: A.P. Bohemier, Survival Systems International -- Lifeboat course and helicopter ditching drill;

   b. Oil rig visit -- Bow Valley's "Bow Drill 1" in Halifax Harbour -- Discussion of semi-submersible operation and survival training aboard the rig;

   c. Meeting: P.L. Potter, The CORD Group Ltd. -- Marine Emergency Duty Survival Course;

   d. Meeting: A. MacDonald, Halifax Nautical Institute -- Marine Emergency Duty Survival Course; and

   e. Meeting: T.H. Lander, COGLA, and R.M. Hattie, Rowan Companies, Inc. -- Interview with survivors of Rowan Gorilla I regarding their seasickness experiences.

3. Helsinki, Finland

   a. Meeting: J. Janson, National Board of Navigation -- Discussion of liferaft recovery using helicopter hoist; and

   b. Visit: Dr. L.A. Laitinen, Central Medical Hospital -- Discussion of seasickness in Finnish Navy.

.../2

4. Trondheim, Norway

a. Tour: P. Werenskiold, Norwegian Marine Technology Research Institute -- Discussion of design of conventional and free-fall TEMPSCs, seating arrangements and impact conditions in free-fall lifeboats, ship motion in wave tank, Ocean Ranger investigation, and Alexander L. Kielland accident;

b. Meeting: A Pasche, The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) -- Discussion on motion sickness;

c. Meeting: T. Sten, Human Psychology Division, SINTEF -- Discussion of disaster psychiatry in platform evacuation; and

d. Meeting: O. Ingstad and T. Ulleberg, Human Factors Division, SINTEF -- Discussion of helicopter transit to/from Mobile Offshore Drilling Units.

5. Bergen, Norway

a. Tour: Norwegian Underwater Technology Centre (NUTEC) -- Underwater escape training and free-fall lifeboat course observation; and

b. Meeting: Dr. O.I. Molvaer, Research Scientist, NUTEC -- Discussion on training and confidence building in free-fall lifeboats.

6. Rosendal, Norway

a. Tour: Harding Safety GRP lifeboat and free-fall lifeboat manufacturing plants; and

b. Meeting: P. Brinchmann, Design Engineer from Harding, Oslo branch -- Discussion of lifeboat design, seasickness, international lifeboat standards and installation problems of free-fall lifeboats on semi-submersibles.

7. Gosport, United Kingdom

a. Visit: Institute of Naval Medicine -- Discussions with Surgeon Commander H. Oakley, Royal Navy, on marine incidents in the navy, review of seasickness in marine accidents; and

b. Meeting: Dr. J.F. Golding, Senior Psychologist, Institute of Naval Medicine -- Discussion of seasickness and anti-motion sickness drugs.

.../3

8. London, United Kingdom

a. Meeting: Emergency Evacuation Committee Rescue and Recovery Work-Group (Chairman - J.S. Austin, U.K. Department of Energy) -- With representatives from oil industry, duscussion of safety matters at sea; in particular, as they relate to seasickness and survival of TEMPSC occupants in the North Sea.

9. Aberdeen, Scotland

a. Tour: Robert Gordon's Institute of Technology (RGIT), Offshore Survival Centre -- Discussions with Dr. I.M. Light on North Sea survival and Ocean Odyssey TEMPSC abandonment; and with Capt. M.G. Greenen on practical aspects of seasickness;

b. Attendees at RGIT Lifeboat Coxswains Course, and Underwater Escape Training Session -- Discussions with I. Watson and rig workers on various aspects of course;

c. Oil Rig Visit: Mobile Oil's "Beryl Bravo" with Messrs. F. Huet, P. Woolhouse, and D. Clarke in the North Sea off the Shetland Islands -- Discussions on rig abandonment, TEMPSC launching and rig safety procedures; and

d. Meeting: I.G. Wallace, Safety and Environmental Co-ordinator Northern Operations, CONOCO (UK) -- Discussions on survival suits, helicopter ditching and seasickness in lifeboats.